Rural energy matters

the Dhanawas experience

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teri

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Preface

More than three decades have passed since the problems of energy scarcity and efficiency in the rural areas were recognized at the policy level. Since then, several measures, mostly in the form of national-level programmes, have been put in place to meet the growing energy needs of the rural people. India can boast of one of the largest rural and renewable energy programmes in the world and an exclusive Ministry for Non-Conventional Energy Sources. However, considering the magnitude and the seriousness of the problem, the impact of these efforts has been limited. The reasons are several, but perhaps the most significant has been a lack of appreciation of the sociocultural and geographical diversity existing in the rural areas of the country. The insensitivity to the sociocultural reality in which programmes have to be implemented and technologies have to be used has greatly contributed to reducing the confidence of the people in the utility of renewable and energy conserving technologies. In such a scenario, the relevance of field-based research assumes greater importance.

TERI initiated work in village Dhanawas to gain field experience in planning for the energy needs of a rural community and finding sustainable solutions to meet these needs. This commitment was also reflected when in 1986, expertise within the Institute was drawn together to form the Rural Energy Group to work solely on energy issues in the rural areas.

The wealth of experience gained from the 15 years of association with the people of Dhanawas is of significance for everyone involved in the field of rural energy and development. The experience is unique for Dhanawas represents one of the fast-growing areas of the country with strong urban linkages and an energy system dominated by biomass that is typical of a majority of villages. The experience is also unique for it is not restricted to technology R&D, but has a wider developmental perspective encompassing the sociocultural and institutional aspects in technology design and application, programme planning, monitoring, and evaluation. The book, therefore, does not dwell much on the technologies, but the processes that make these technologies work in rural areas, which are often overlooked by planners and policy makers.

The reference of experience gained from working in a single village may be too small to make generalizations at the national level; however, it is significant for the issues it highlights and the possibilities it presents. The book, therefore, does not attempt to present solutions, but examines the issues in rural energy in the light of the understanding and insight gained from Dhanawas and its people.

Acknowledgements

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Foreword

The fuel crisis of the early 1970s brought home to the planners and policy makers in India the pressing need to deal with the problem of unsustainable use of commercial energy and the escalating crisis of dwindling biomass resources. To coordinate and intensify activities in new and renewable sources of energy, the Department of Non-Conventional Energy Sources was created in 1981 in the Ministry of Energy. Biogas and solar energy were recognized as the key alternatives, and concerns related to the conservation of forests led to R&D in these areas. In 1981/82 the first national renewable energy programme, the NPBD (National Project on Biogas Development), was launched, followed by the NPIC (National Programme on Improved Chulhas) in 1983. These programmes were conceived as centralized target-oriented technology-driven programmes with a 'subsidy' component to benefit the poorest of the poor in the rural areas. The concept of integrated energy systems gained popularity and institutional and socio-administrative aspects in rural renewable energy programmes were highlighted. In 1992, the Department was upgraded into a full-fledged Ministry of Non-Conventional Energy Sources making India the only country with a separate ministry for new and renewable sources of energy.

Today, India has one of the largest rural and renewable energy programmes in the world. However, the magnitude and gravity of the problem require action on a larger scale. Though the NPBD and the NPIC are touted as the largest programmes in terms of investment and scale, they would take more than five decades to fulfil the entire potential in the country. Even where the programmes have been implemented, the impact has been limited, bringing only negligible improvement in the energy options available to the rural masses. A majority of the rural population continues to rely on traditional fuels – firewood, animal dung, and crop residues – to meet most of their energy needs. Women continue to suffer ill-effects on their health because they have no choice but to burn poor quality biomass fuels in their ill-designed cookstoves. Children still study in the poor light of a kerosene lamp. The village economy continues to suffer as power supply is neither adequate nor reliable. More alarmingly, the lot of the rural folk does not seem to have prospects for getting any better in the future, with projections indicating an increase in reliance on traditional fuels.

Much analysis has been done on why the rural energy problem stays unabated despite the vast amounts of resources invested. In most cases, the answers lie with the people who, unfortunately, have not been made part of programme planning and implementation. Though decentralized planning was encouraged through programmes such as Urjagram and the Integrated Rural Energy Programme, they could not become workable models largely because they did not envisage any role for the local communities. Perhaps what contributed the most to this is the fact that there has been no change, whatsoever, in the strategy for planning and implementing rural and renewable energy programmes since their inception. To make matters worse, there is no forum where the findings of numerous evaluations, impact assessments, case studies, field research, etc., done by independent agencies and research and academic organizations can be presented to policy makers and planners. This is not to say that there have been no strategic changes in programmes over the years. The solar photovoltaic programme, wherein a commercial programme is also being implemented, is a case in point. But even here, the parallel subsidy programme has only led to contradictions and waste of resources.

The failure of many rural and renewable energy programmes to meet the expectations of the people has had several adverse effects. Rural people are often apprehensive about whether renewable energy technologies can actually work in the field. Even the mature technologies fail to perform satisfactorily in the field due to lack of repair and maintenance services, quality control, user education and training, etc. But these aspects are still not given their due in programme planning. An even bigger challenge is to find ways in which the programmes can be made more sensitive to the sociocultural reality in which they have to function.

In this context, field-based research is of immense value to everyone concerned with the worsening plight of the rural people who continue to struggle in trying to meet their daily energy requirements. Action-oriented field-based research gives an opportunity to work in real-life situations, work 'with' the people and not merely 'for' them, and holistically look at the process of rural development; generating a wealth of information critical to the success of energy technologies and programmes in rural areas. This book is a result of 15 years of work of TERI with the people of Dhanawas assessing their energy needs, aspirations, and priorities and trying to find means to fulfil these needs by working jointly with the community. The book aims to contribute to the existing literature on rural energy (which is generally meagre), providing insights into some of the issues which necessarily play a crucial role in sustaining energy programmes in rural areas.

R K Pachauri
Director, TERI

Chapter 1

Action-oriented research: a beginning in Dhanawas

The focus of activities in TERI during its initial years of establishment was on documentation and information dissemination. Since its transformation into a research organization in the early 1980s, the Institute has been committed to socially-responsible research that aims at finding sustainable solutions to energy and environmental problems faced by different sections of people in India. TERI's rural energy activities have been a prominent part of this endeavour for the past 15 years. These activities range from providing inputs to national and regional energy policy initiatives of the government to developing methodologies for decentralized rural energy planning to carrying out applied and action-oriented research at the village level. Thus, the efforts in the rural energy area have been a conscious attempt to integrate projects at the grass-roots level and apply the learning to make recommendations at the national level.

The developments in the country in the 1980s (detailed in Chapter 2) in policy-making, programme planning, and research furthered the Institute's mandate to understand this complex energy system and find sustainable energy options through action-oriented research work. At the same time, the Institute supported numerous research projects, sponsoring more than 100 R&D projects in the early 1980s. These included projects on energy planning, energy surveys, technology development and demonstration, international workshops, techno-economic feasibility studies, technology forecasting, energy audits, solid waste management, resource assessment, etc.

Dhanawas: an entry point

Since 1984, village Dhanawas in Gurgaon district, Haryana has been the focal point of TERI's action-oriented research work on rural energy, which attempted to promote a sustainable energy pattern in the village. TERI aimed to provide sustainable energy options to the villagers using renewable sources of energy. Towards this end, the Institute was involved in understanding the energy system of Dhanawas, assessing the needs and priorities of the villagers, developing and demonstrating appropriate technologies to meet their energy requirements, disseminating these technologies, and studying the process of their adoption.

Specific objectives of the project were as follows (TERI 1986).

1 Study the energy supply and consumption patterns.
2 Identify energy needs at village and household levels.
3 Demonstrate energy-efficient devices, disseminate appropriate energy technologies, and develop devices to meet the energy demand.

Considerable efforts were also made to deal with the 'qualitative' aspects typically involved in any rural development work: village-level politics, inter-group rivalries within the village, and other similar dynamics. An important component of TERI's efforts in the village has been the setting up of requisite institutional systems for the management of technologies and programmes.

In Dhanawas, TERI was involved in the development, testing, and demonstration of a large number of energy technologies. These technologies can be broadly classified into three categories.

1 Technologies that were developed/modified/refined and disseminated (e.g. the TERI model biogas plant and improved cookstoves). The villagers accepted these well and the devices are still in use.
2 Technologies that were experimented with, but could not be disseminated due to high cost and unsuitability to local conditions (e.g. solar water heater, solar shallow pond).
3 Technologies that were field tested in Dhanawas for some time and on which R&D is ongoing (e.g. biomass gasifiers).

Dhanawas: a learning ground

The experience in Dhanawas has been of great learning value for everyone involved with this action-oriented research work. The long association with a single village provided an excellent opportunity to study the impact of interventions in the light of the external environment (government policies, emerging technological options, needs and aspirations of a rural community, increasing rural incomes, etc.), which has undergone a transformation during this period. Not only this, it was also fruitful to examine how the Institute modified its approach to work in the village incorporating such changes. The influence of such factors was particularly profound in Dhanawas considering its proximity to such urban centres as Gurgaon and Delhi. It was thus possible to highlight appropriate experiences and draw lessons from the same. The work in Dhanawas has also led to a deeper understanding of the techno-economic viability and sociocultural compatibility of renewable energy technologies and the relevance of the sociocultural and political environments, which drive technologies and programmes. This understanding largely influenced the manner in which the Institute came to view the rural energy problem and ways to tackle it. Dhanawas was hence an entry point for the Institute into action-oriented research on rural energy.

In 1986, a separate group, the Rural Energy Group, was created within the Institute to contribute towards meeting the formidable challenge of finding sustainable solutions to the growing energy needs of the rural population. Dhanawas was the initial learning ground for the group. Banking on the knowledge and understanding gained from Dhanawas, TERI gradually expanded its activities to other geographical areas representing different agro-climatic conditions. These regions include Solan in Himachal Pradesh, Sultanpur in Uttar Pradesh, Jaisalmer in Rajasthan, Vellore in Tamil Nadu, Kumari Kata in Assam, and Wardha in Maharashtra. The knowledge accumulated through field experiences in these areas helped TERI understand (1) the complex nature of the rural energy system; (2) appropriate alternative technologies; (3) processes of technology adoption; (4) institutional mechanisms; (5) the influence of social structure and cultural processes; (6) the role of leadership; (7) the significance of community organization and participation; and (8) the need for capacity building to plan, implement, finance, and manage rural and renewable energy programmes.

The work done in Dhanawas also built the Institute's capacities to plan, implement, monitor, and evaluate such activities in different rural areas of the country. Specific methodologies were developed and refined from the work done in Dhanawas, which include, among others, rural and renewable energy planning, technology and programme evaluation, training, and documentation. These are now widely used both within the Institute and outside. Notably, the Institute has earned the reputation of being amongst the very few organizations in the country which has the expertise to carry out rural and renewable energy planning, evaluation, and training. It has carried out numerous planning exercises at the block and district levels for the Government of India covering different geographical areas: Mandla, Madhya Pradesh; Jodhpur, Rajasthan; Ladakh, Jammu and Kashmir; North Tripura, Tripura; Changlang, Arunachal Pradesh; etc. Similarly, the Institute has also carried out evaluations of various technologies and programmes for the government as well as international agencies. TERI has imparted training on rural energy and issues therein, rural and renewable energy technologies, projects and programmes, energy planning, and evaluation to government officials, researchers, and NGOs (non-governmental organizations). The 'implementation strategies' that evolved during the 15 years of association with Dhanawas have tremendous scope for replication in other regions, with suitable modifications taking into account sociocultural, geographical, and economic diversities.

The close association with the people led to a shift in TERI's focus on 'technologies' to conceptualizing a holistic development framework by integrating energy–environment issues/programmes/technologies in the overall process of development of rural areas. This shift in focus occurred with the realization that

- rural energy problems are location specific and hence, uniform solutions are not feasible
- sociocultural and economic diversities, which are so characteristic of the rural areas, have to be taken into account while designing programmes
- institutional mechanisms have to be set in place for long-term sustainability of rural energy programmes
- energy can be a means for development and not an end in itself.

The Institute, therefore, ventured into new areas of research such as gender issues in rural energy and natural resource management, participatory planning and management of programmes, programme integration, etc. The focus of the Institute from energy issues has also expanded to include land development, irrigation, credit mobilization, institutional mechanisms, local governance, employment generation, etc.

This experience was also made rich by the fact that a large number of professionals were involved in the experiment over the years, who brought in their own ideas and perspectives, and tried out new approaches and innovations. As a result of this, today, a huge repertoire of information and in-depth knowledge exists within the Institute. This book is an effort to synthesize this body of know-how and information as well as disseminate the lessons learnt from the Dhanawas experience to a wider audience.

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TERI. 1986
Status report on rural energy extension activities in Dhanawas
Submitted to the Department of Science and Technology, Government of Haryana, Chandigarh
New Delhi: TERI

apter 2

Energy scenario in rural India

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The rural population of India, which currently constitutes 70% of the total population, is expected to exceed 900 million by 2010 if it follows the current rate of growth. Primarily engaged in agriculture, the rural populace depends heavily on biomass for their energy needs. Every addition to the population brings with it a corresponding increase in the energy consumption, thus increasing the stress on the environment. Meeting the energy requirements of these vast numbers in a sustainable manner is thus a formidable challenge for the country.

Energy use

Sectoral break-up

The household sector accounts for nearly 75% of the energy consumption. Within this sector, cooking is the largest energy consuming end use accounting for almost 90% of household energy, followed by lighting and heating. The energy consumption pattern in the household sector is detailed later in the chapter.

In the agriculture sector, animate energy (human and draught power) accounts for more than one-third of the total energy consumed. The share of electricity in the farm sector was 28.7% in 1992/93; in 1950/51, this had been a mere 3.9% (TERI 1998). This sharp rise can be attributed to the increase in the number of electric pumpsets, used for irrigation, from 1.6 million to a whopping 10.3 million between 1970/71 and 1993/94. Diesel, used in pumpsets and tractors that assist in tilling and harvesting, is the other major inanimate energy input. From 1970/71 to 1993/94, the number of diesel pumpsets more than tripled from 1.5 to 4.9 million. Diesel consumption by agriculture is 10% of the total diesel consumption (TERI 1998). The break-up of energy consumption in the agriculture sector is given in Figure 1.

Other sectors that consume significant quantities of biomass energy in the rural areas are small industries and commercial establishments (hotels, restaurants, shops, etc.). However, reliable statistics on the extent of consumption is not available. Available evidence suggests a high level of fuelwood consumption. One estimate puts the annual fuelwood

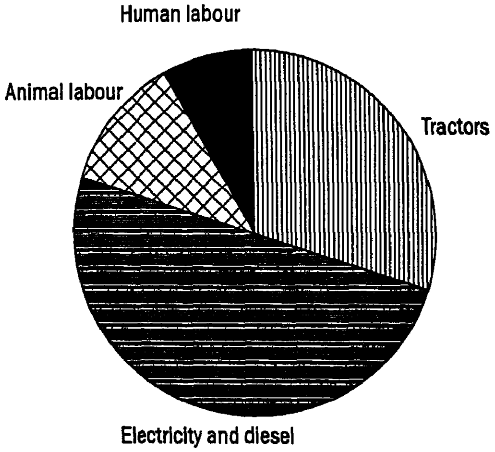

Figure 1 Energy consumption in agriculture sector: 1995/96
Source TERI (1998)

consumption in these sectors at 10 million tonnes (TERI 1996a).

Statistics on the energy consumption pattern in the rural transport sector is not available.

Energy onsumption in the household sector

Biomass fuels provide 85%–90% of the domestic energy and 75% of all rural energy (Natarajan 1985). Fuelwood is the largest contributor to energy use in rural areas, followed by animal dung and crop residues (Figure 2).

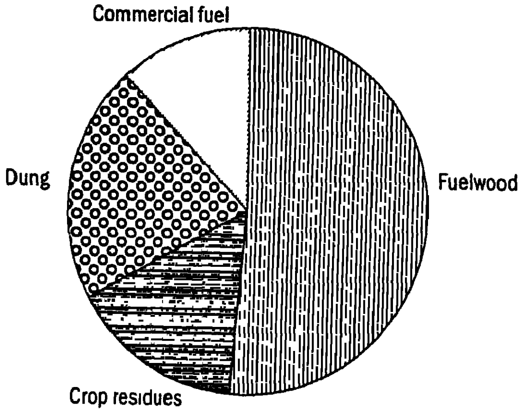

Figure 2 Energy use in the rural domestic sector
Source Natarajan (1985)

In spite of significant increases in the supply of commercial energy, the consumption of commercial fuels like LPG (liquefied petroleum gas) is still negligible in the rural areas with only 1.3% households using the fuel for cooking (TERI 1998). On the other hand, biomass use continues to increase. The monthly per capita consumption of firewood increased from 16 to 17 kg over the period 1987/88 to 1993/94. The Planning Commission estimates the fuelwood requirement at 180 million tonnes in 2001, a substantial increase from the actual consumption of 162 million tonnes in 1996 (GoI 1997a). As Figure 3 shows, the use of firewood in the form of logs has tripled in 15 years. The share of firewood (percentage of households using a particular fuel) in the form of twigs fell from 67.6% in 1978/79 to 62.9% in 1992/93; during the same period, the share of firewood in the form of logs rose dramatically from 18.95% to 32.49% (Agarwal 1998). A definite shift from other fuels to firewood has also been observed.

The energy consumption pattern varies considerably across different states and districts because of the geographical and ecological diversity in the country. For instance, the consumption of fuelwood ranges from 2.04 kg per household per day in Haryana to 14.14 kg per household per day in Orissa (TERI 1995). The fuel mix also varies from region to region depending on the resource endowments. Fuelwood consumption is high in states that have considerable forest cover; for instance, in Arunachal Pradesh it is 10.4 kg per household per day and in Manipur it is 10.34 kg per household per day. On the other hand, consumption of dung cakes is high in states like Uttar Pradesh (4.95 kg per household per day) and Rajasthan (3.41 kg per household per day) that have little biomass cover (TERI 1995). Crop residue, being inferior in

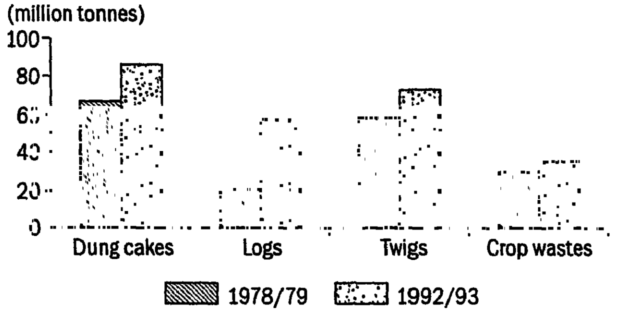

Figure 3 Energy consumption in rural households
Source Natarajan (1997)

quality, is used in most areas as a back-up fuel when there is a shortage of other fuels.

The energy consumption pattern in rural areas is determined by the availability of biomass resources, people's access to these resources, their competing uses, and availability of commercial energy sources. Other factors that do not strictly fall within the energy system, but play a crucial role in determining people's choices regarding fuels, include income levels, purchasing power, and accessibility to urban centres.

There has also been a major shift in household consumption expenditure, which is indicative of the lifestyle changes. Most households in the higher MPCE (monthly per capita expenditure) class level use less of firewood and chips as their primary energy source for cooking. However, the percentage of households in all MPCE levels in the rural areas using dung cake as the primary source of energy for cooking remains constant as domestic cattle is maintained by these households (GoI 1997b). In 1978/79, one-third of the households was purchasing firewood logs, while in 1992/93, just about one-sixth was doing so (Agarwal 1998). The 50th round of the NSS (National Sample Survey) found that only two per cent of rural households could afford to use kerosene or gas as the primary source of energy for cooking (GoI 1997b).

Rural–urban disparity

An issue of concern is the disparity that exists in the energy use between the rural and urban households. The rural–urban disparity exists in the type of fuels and cooking devices used and in the quantum of energy use. While the monthly per capita consumption of firewood and chips has increased in rural areas, it has declined in urban areas between 1987/88 and 1993/94 (Figure 4).

In the rural areas, the shift to commercial fuels has been marginal. For instance, only one per cent of the households in the rural areas has switched over from firewood and chips as a source of cooking since 1987/88 (GoI 1997b). While the dependence of rural households on dung cake, coke, and coal has fallen and that on kerosene and gas has risen over successive NSS rounds, the percentage of households (77–79) dependent on firewood and chips has remained constant (GoI 1997b). The rural electrification programme, which is the largest rural energy programme today, claims to have electrified more than 85% of the 580 000 villages in the country (CEA 1996). But, only 37% of the rural households has electricity connections compared to 83% urban households (GoI 1997b). On the other hand, during 1983 to 1993/94, the

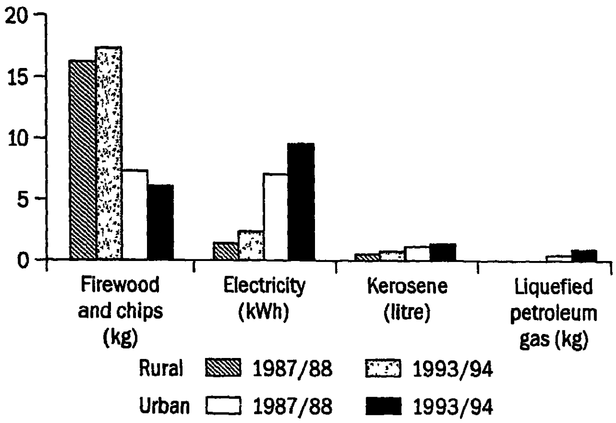

Figure 4 Monthly per capita fuel consumption
Source NSSO (1997)

use of electricity for lighting has risen by 22% in rural areas as against an increase of 19% in urban areas (GoI 1997b). However, taking total figures, the rural–urban divide is still wide. As against 27.2% of the urban households, only 1.3% of the rural households use LPG for cooking (CMIE 1996a). A similar disparity exists in the case of kerosene, which is promoted predominantly as a subsidized fuel for the poor. According to 1991 census, while 23.62% urban households use kerosene as a cooking fuel, only 1.34% rural households use kerosene for cooking (CMIE 1996b). The percentage of households using kerosene as the primary source of energy decreased from 74 to 62 in the rural areas and from 27 to 16 in the urban areas between 1983 and 1993/94 (GoI 1997b).

Impacts of over-dependence on traditional fuels

The over-dependence on traditional fuels has led to several ecological and health problems. Though no direct correlation between deforestation and fuelwood use in the rural areas has been established, fuelwood extraction could exacerbate the process where the land is already degraded (TERI 1996a). Of the total requirement of 200 million tonnes, 102 million tonnes is expected to be met from forest areas and 98 million tonnes from farm forestry. It is estimated that about 18 million tonnes is available as fuelwood annually on a sustainable basis from the forests. This means that the remaining requirement of 84 million tonnes is to be met by excessive removal from forest areas, putting severe stress on our forest resources (GoI 1997a). Loss of green cover and burning of biomass in inefficient traditional cookstoves significantly contribute to greenhouse gas emissions. In India, it is estimated that of the 68.3 million tonnes of carbon released annually due to biomass burning, fuelwood accounts for 82.3% (Kaul 1993). Wood burning also produces products of incomplete combustion which have a global warming potential of 20%–110% as much as carbon dioxide itself (Smith 1992).

The use of agricultural residues and animal dung as energy sources instead of fertilizers reduces the soil nutrient level. It has been estimated that out of the total nitrogen content of dung production of 1.35 million tonnes annually, 0.4 million tonnes is lost annually through the burning of dung as fuel (Ravindranath and Hall 1995).

The use of biomass fuels has several human costs attached to it, which go far beyond economics. Due to increasing shortages, women are being forced to spend more time and walk longer distances to collect fuelwood (Agarwal 1986, 1991). The burden of carrying large head loads of wood over long distances is known to cause ailments such as muscular pains, back ache, and pregnancy-related problems. Further, the burning of biomass in inefficient and poorly vented appliances is a serious health hazard for women and children (Smith 1993). In a study conducted by TERI in the Garhwal Himalaya, the measured mean daily exposure of women (due to cooking) to TSP (total suspended particulate) was found to be as high as 17 mg h/m^3 (Saksena et al. 1992). In the Delhi slums, which represent similar indoor environment in terms of the device and the fuel used, TERI found that the exposure of infants (0–12 months) to RSP (respirable suspended particulate) was 5 to 77 times more than the WHO standards for PM10 (particulate matter less than 10 μm) (TERI 1996b).

Yet another social dimension of the problem is that of head loading. As fuelwood becomes scarcer for both rural and urban poor, head loading serves as a regular source of livelihood for a large number of rural poor. This increases the tendency to exploit biomass resources. Estimate shows that 2 to 3 million people are engaged in head loading as a regular profession, supplying fuelwood to urban markets (CSE 1985).

Government initiatives

Recognizing these facets of rural energy consumption patterns, the GoI (Government of India) has taken steps to improve the supply of existing fuels and introduced NRSE (new and renewable sources of energy) as alternative fuels to meet the demands of the rural population. India's initiative in the field of renewable energy began in the 1950s with the introduction of technologies such as biogas and smokeless chulhas. Around this time, Indian scientists had designed solar devices for water heating and cooking (MNES 1998). However, these remained isolated and disparate efforts for many years. It was only after the energy crisis of the 1970s that renewable sources of energy were explored as a possible solution to the impending energy shortage. The government, through its various committees such as the Fuel Policy Committee (1974), Working Group on Energy Policy (1979), Advisory Board on Energy (1985), and Energy Demand Screening Group (1986), formulated several programmes to meet the energy needs of the rural people.

Initially, the thrust in this sector was on fuel substitution by supplying kerosene through the public distribution system and power through rural electrification. However, emphasis was also given on exploring alternative energy sources taking into account the growing environmental concerns and dwindling reserves of fossil fuels. In 1981, CASE (Commission for Additional Sources of Energy) was established to formulate policy and programmes for the development of NRSE. A year later, the DNES (Department of Non-Conventional Energy Sources) was set up for R&D, demonstration, and dissemination of renewable and rural energy technologies.

The most significant step towards addressing the energy needs of the rural areas was the launching of the NPBD (National Project on Biogas Development) in 1981/82 and the NPIC (National Programme on Improved Chulhas) in 1983. The NPBD is the largest rural energy programme in terms of investment and the NPIC is the largest in terms of number of devices disseminated. The wind energy development programme was also launched.

During the 1980s, the emphasis of the government was to develop and demonstrate new and renewable energy technologies. In line with this thinking, the focus of the activities was to support intensive R&D activities, set up demonstration projects, and create a demand through government subsidies. In 1987, IREDA (Indian Renewable Energy Development Agency) was established under the DNES for developing, promoting, and financing commercially-viable NRSE in the country.

While such rural and renewable energy programmes were being formulated and implemented at the national level, energy research was also initiated. Studies were carried out to build a database on rural energy use in the country (NCAER 1981, Natarajan 1985). Detailed micro-level rural energy studies were also carried out to understand the energy system in the rural areas (Ravindranath et al. 1981; Reddy 1981).

With the liberalization of the economy, the 1990s saw a shift in the renewable energy policy towards commercialization and private sector participation. Ten years after its setting up, the DNES was upgraded into a full-fledged ministry called the MNES (Ministry of Non-Conventional Energy Sources) in 1992, thus making India the only country that has a separate ministry for the promotion of renewable energy sources.

Apart from the NPBD and the NPIC, a large number of technology-specific programmes have been introduced in the country. These include the Solar Cookers Programme, Solar Photovoltaic Demonstration and Utilisation Programme, and Solar Thermal Programme. However, these are yet to make a significant impact in terms of penetration or in terms of benefits accruing to the target population.

Performance and achievement

Some of the rural renewable energy programmes have made substantial improvements in the quality of life of people, especially women and children. However, when viewed in the light of the magnitude and seriousness of the problem, the overall impact of the renewable energy programmes in the rural areas has been limited. It has been estimated that the biogas and improved chulhas programmes together save about 10–11 million tonnes of fuelwood, constituting about five per cent of the total annual fuelwood consumption in the country (TERI 1996a). The scale of operation and the dissemination rate are very low; so far, these programmes have covered only nine per cent of the total rural households (TERI 1996a). In fact, at the current rate of installation, it will take about 60 years to meet the existing potential of biogas plants and over 50 years for that of improved chulhas. By that time, we might actually face a resource constraint in terms of availability of animal dung. Reasons for this slow rate of dissemination are (1) high cost of technology, especially biogas; (2) high subsidies on commercial fuels, which make the economics for renewables appear more unfavourable than it actually is; (3) inadequate budgetary allocations for the renewables sector; and (4) inadequate emphasis on R&D for technologies for the rural sector (TERI 1994a).

Another factor largely responsible for the inconsistent performance of rural renewable energy programmes is the overall approach adopted in their planning and implementation. Major government programmes such as the NPBD and the NPIC are technology-driven programmes with fixed annual targets and budgetary allocation based on targets achieved. Similarly, large afforestation programmes are focused on nursery raising and planting with annual targets of area covered (public and forest lands), seedling distribution for planting, generation and distribution of quality seeds, etc.

Lack of programme integration has also reduced the impact of such programmes. For example, the potential of afforestation programmes to augment the availability of biomass is limited since fuelwood conservation programmes do not supplement these. This also results in waste of resources and duplication of efforts.

Area-based programmes and decentralized energy planning

It has been recognized that because of the extremely area-specific nature of the rural energy problem and the wide variations that exist in the sociocultural environments in rural areas, energy planning at a decentralized level can perhaps make a better impact than target-based uniform technology-specific programmes. Experience has shown that energy programmes can make a substantial impact on the rural energy scenario only if these are integrated with the development priorities of the people[1] and are in consonance with sociocultural realities. The localized nature of the rural energy system makes planning for area-based energy programmes necessary. The supply of biomass fuels is determined by the local situation. Hence, accounting for the need (demand and supply) and designing an intervention addressing that need should be done at similar geographical scales.

An attempt towards decentralized area-based energy planning at the block level was made in the IREP (Integrated Rural Energy Programme) that was started as part of the Sixth Five-Year Plan, and at the village level, in the Urjagram programme during the Seventh Plan. The Urjagram programme is in the line of demonstration projects (using local resources to make a village self-sufficient in energy). The IREP, on the other hand, incorporates the distinction between subsistence and productive energy requirements and conceptualizes strategies for making the interventions (Sinha, Ramana, and Joshi 1994). These programmes are ongoing and have, to an extent, tried to decentralize energy planning in rural areas. The focus of programmes such as the IREP, however, continues to remain on numbers of systems to be installed and are essentially technology driven. There is also no 'ownership' for maintenance, that is, there are no institutional mechanisms created for the maintenance of the devices. Hence, most devices are not used.

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[1] Some generalizations can be drawn vis-à-vis the common needs of rural communities. In most instances, the needs of the people are economic in nature – related to income generation, employment creation, and infrastructure development.

The weaknesses of the IREP have also been recognized at the policy level. The Ninth Plan document states, 'The programmes which were socially oriented like biogas, improved chulhas and the IREP could not make the expected impact in changing the lifestyle of the people mainly because of the weak institutional set-up, lack of suitable mechanism to maintain and put the non-functional systems back into operation, lack of locally available trained and skilled manpower where such systems were installed, etc.' (GoI 1997a).

The concept of integrated planning for overall development, on the other hand, is still to make a real headway. Thus, though there is a realization at the policy level of the need for integrating programmes for the development of non-conventional energy sources into other development programmes of the centre and state governments (GoI 1997a), not much seems to be happening at the level of programme planning and implementation. Rural and renewable energy programmes continue to be planned and implemented in isolation to programmes on rural sanitation, health, literacy, housing, infrastructure development, etc. There is also little integration of renewable energy programmes at the grass-roots level. Targets of programmes like the NPIC and the NPBD are determined independent of each other such that, for a given region, the combined target of biogas plants and improved cookstoves could be far in excess of the potential demand. Thus, organizational resources in pushing both are wasted (Ramana 1998).

The need to integrate energy interventions with 'other' programmes also stems from the fact that energy is not a priority issue for people in most rural areas. Consequently, energy programmes are often faced with the problem of facilitating people's participation. In isolation, energy programmes are unable to make a significant impact on the lives of the rural people.

Role of field-based research

Field-based research in rural energy is important on account of the highly local nature of the rural energy system and the sociocultural diversity so typical of the rural areas of the country. It gives an understanding of what will and will not work in a rural setting. For example, measuring the performance of energy technologies in the field is crucial to determine what the technology is actually capable of delivering. Experience has shown that presumptions about technologies (e.g. the improved cookstove) performing as well in households as in laboratories do not hold good (Barnes et al. 1993). Field experiments have also shown that the reduction in fuel use decreases with the age of the improved cookstove (Ravindranath and Hall 1995). Similarly, there are geographical, economic, and sociocultural factors that determine the acceptance and use of any technology. The most crucial factor that determines technology acceptance is whether it addresses a felt need of the user. To cite the example of improved cookstoves again, the elimination of smoke may be a more important consideration than conserving biomass in using improved stoves. Studies (Barnes et al. 1993, TERI 1994b) have shown that when people are not short of wood or do not perceive any shortages, they see no reason to adopt improved cookstoves and conserve fuelwood. It is thus important to know the changes the people want in their traditional energy system and to what extent they are willing to alter their lifestyles for accommodating the changes envisaged. Studies have shown that a technology is likely to have a better chance of being accepted if it does not ask for too many changes in the lifestyles of the people. In an evaluation of 10 Urjagram villages conducted by TERI (1994b), the disseminated improved cookstoves were found to be unsuitable in terms of

- the fuel used (the dung cakes did not fit in the chulha – Uttar Pradesh)
- pots (big pots could not be used – Madhya Pradesh)
- kitchen (chances of fire – Uttar Pradesh)
- cooking practices (unsuitable for making rotis – Uttar Pradesh and Haryana)
- cultural practices (the tribals shift houses very frequently – Madhya Pradesh)
- convenience (removal of ash is extra work – Himachal Pradesh).

Field research, therefore, gives an understanding of how the needs and priorities of the people change with time, what brings about these changes, and how the programme can be designed to respond to such changes.

Conclusion

Rural energy programmes, in their present form, can contribute only in a small way to meeting the energy needs of the people. To be able to make a significant contribution in the future, there is clearly a need for working towards reducing costs and making the technologies affordable to a larger section of the rural population. Another important requirement is to have a rural energy research agenda, which would focus on designing technologies more suitable for rural applications.

It has to be recognized that the traditional focus on fuel conservation alone cannot be the criterion for selection of technologies to be promoted in the rural areas. In this context, efforts invested in field-based research projects have an important role to play. Intervention packages on rural renewable energy can be designed after studying in depth the local scenario in terms of lifestyle, energy use pattern, needs and preferences of the people, etc. Small field-based projects also provide planners an opportunity to actively involve people in designing, implementing, and monitoring projects. Most importantly, they provide an excellent opportunity to operate in real-life situations and get valuable insights into various aspects of programme planning and implementation.

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hapter 3

Entry in Dhanawas

Rural energy matters: the Dhanawas experience 23-48

One of TERI's goals is to find means to tackle the immense problems of depletion of earth's energy sources and the existing methods of their use. Believing that rural energy interventions would go a long way towards this, TERI decided to take up a project on integrated rural energy development for a specific village community. Alongside, researchers at the Institute's laboratory in Pondicherry worked on the development of a biomass-based gasifier and a biogas plant model. In 1984, these were ready for demonstration and testing in the field, setting the scene for action-oriented research in the rural energy sector.

Selection of the village

The task was to select a village for field-based research. Considering the fact that the technologies developed by TERI were relatively new and untested in the field, necessitating the constant monitoring of the devices, proximity of the village to TERI was an important parameter for selection. Thus the search for a suitable village was restricted to the districts adjoining Delhi. TERI was also keen on gaining field experience in land reclamation through plantation activities. For experimentation in this field, it was essential that the selected village should have degraded soils. Influenced by these research areas and technologies, other parameters considered for selection were (1) the cattle to man ratio for biogas feasibility and (2) cropping pattern and average productivity for feasibility of a crop residue based gasifier.

The Gurgaon district authorities suggested two villages, Gharauli and Dhanawas. After visits and discussions in both the villages, Dhanawas was selected with the help of the Government of Haryana. Dhanawas falls in Gurgaon district, 15 km from Gurgaon city, in the state of Haryana. Figure 1 gives the location of Dhanawas village.

Objectives

The project was envisaged as an attempt to promote a sustainable energy consumption pattern in the village. Specific objectives of the action research work were to

1 study the energy supply and consumption in the village to identify its energy needs

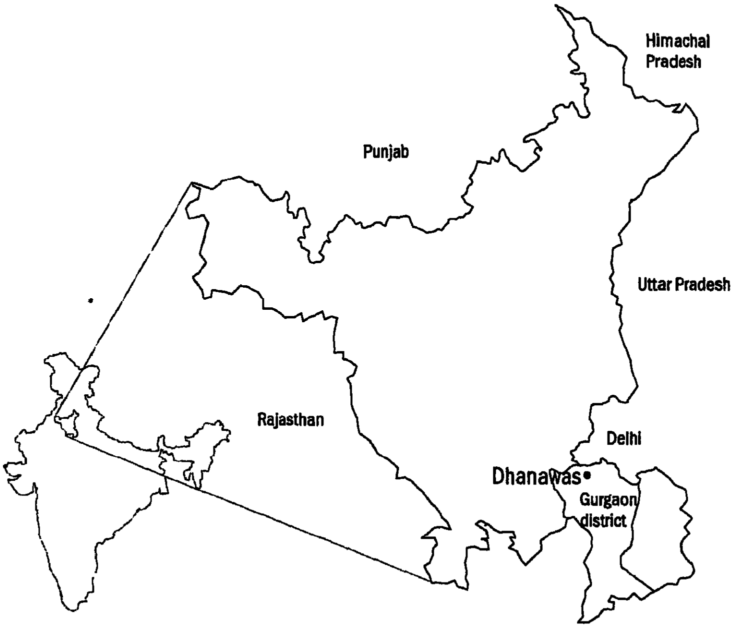

Figure 1 Location of Dhanawas village

2 study the sociocultural context in which energy technologies are to be implemented
3 develop, demonstrate, disseminate, and evaluate appropriate energy technologies
4 improve the fuel supply situation through afforestation and agroforestry
5 develop a local-level organization to manage energy extension activities
6 develop dissemination packages based on the field experiences (TERI 1994).

The need to gain experience in rural field-based work was a driving force for working in Dhanawas. The option of developing a joint project with other field-based organizations working on energy, including NGOs, was explored. However, this did not materialize as there were not many organizations working in the area at that time. The HSWRC (Haryana Social Work Research Centre), Khori, which was still in its infancy, was the only NGO in Haryana working on energy.

History of the land

The history of Dhanawas can be traced back to 300 years when the first settlers started coming in. These early settlers, who belonged to the traditional warrior class, held proprietary rights on the entire land in the village and became zamindars or feudal lords over the years. They controlled land and labour in the region. Other families leased land from them for agriculture and paid them in the form of agricultural produce.

The first major change in this pattern occurred when the Punjab Security of Land Tenures Act, 1953 was passed restricting the rights of a single farmer to ownership of land. In the 1960s, the government initiated a consolidation drive. Prior to consolidation, most farmers had their plots scattered in distant locations. Consolidation of land meant bringing together the scattered holdings of a farmer. Under this, the value of a plot was based on its quality (soil fertility). Hence, the farmers owning scattered fields could be allotted the same value of land in adjacent locations. The land consolidation efforts brought about significant improvements in the production of grain in Dhanawas (TERI 1984).

The Punjab Security of Land Tenures Act, 1953 was, however, not effectively implemented. Accordingly, the Punjab Land Reforms Act, 1972 was enacted that placed a ceiling on the landholding size. The land acquired as a result was to be redistributed among the landless and other weaker sections of the society. However, according to the village elders, many of the landless families, especially the harijans, were unaware of their rights under the Act. Even where they did manage to retain the piece of land allotted to them, these farmers often did not have the means to cultivate them and eventually sold them back to the large landholders.

Fact file

Dhanawas is about 7 km from Faroukh Nagar town, the block headquarters, and about 45 km from Delhi. In 1987, the village had 144 households with a population of over 1000 persons (Kohli et al. 1992). While agriculture was the primary occupation, some people, especially those belonging to the younger generation, were in government service in nearby towns. The primary crops grown in the village were wheat, mustard, sorghum, and bajra. The village had a total cultivable land of 682 acres (1 acre = 0.45 hectare). However, as land was given and taken on lease by farmers both within and outside the village, the total land under cultivation changed every year. When TERI conducted the AIUN (Activities Impact and User Needs) survey in 1987, an area of 719.4 acres was under cultivation. In terms of basic infrastructure, the village had a primary school; for higher education, students had to go to nearby villages or to Faroukh Nagar. There was no primary health centre in the village.

The AIUN survey classified the households into two economic categories (1) those with agriculture as the only source of income, and (2) those in government service or self employed with or without any landholding. The first category was further subdivided on the basis of landholding size. Out of 67 households in this category, 25 were large farmers (owning more than 10 acres), 17 medium (5–10 acres), 14 small (2.5–5 acres), and 11 marginal farmers (up to 2.5 acres). The second category was subdivided on the basis of cultivable land owned or under cultivation, whichever was greater, and the declared income from sources other than agriculture. On the basis of the above criteria, households in both categories were divided into economically well-off and economically weaker-off families. Ninety families fell in economically well-off category and 54 in the economically weaker category.

The large farmers had an average family size of 9.7, which was significantly larger than any other category. The average for the village as a whole was 7.18 and the average for the landless was 6.26.

No consistent trend was seen in education levels. However, the large farmers were found to have an above-average formal education level. The education level of adults was noticeably higher in the landless category than in other categories, barring that of big farmers.

Most households had some cattle or the other: 62% households owned three or more cattle heads and 12% households did not own any cattle (TERI 1984). In 1987, there were 70 cows, 151 buffaloes, 36 bullocks, 215 calves, and over 4000 heads of poultry in the village (Kohli et al. 1992). The average household ownership of cattle heads is given in Figure 2. Large farmers, on an average, had 6.7 cow equivalents. The smallest cattle-holding size (two) was with landless households

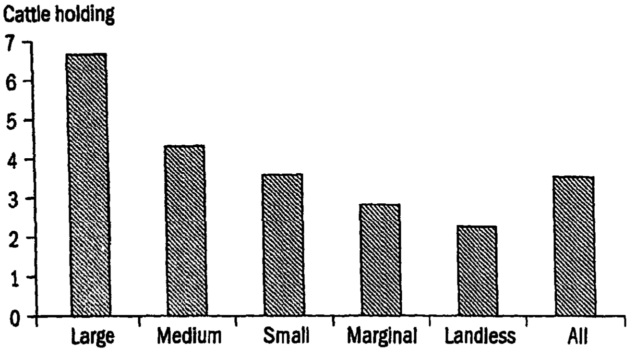

Figure 2 Average household ownership of cattle heads (1987)
Source Puri (1988)

in government service or self-employed. The average holding of cattle heads per household increased with the size of land owned. For this reason, the large farmers had a higher availability of both crop residues and cow dung.

Social set-up

As in most parts of rural India, the village community of Dhanawas was divided into clans, which were locally called 'pattis'. Pattis were based on family lineage – each patti comprised several families bound by common ancestry. Dhanawas had four pattis: Ranjit, Khora, Naga, and Bhagat. Each of these pattis derived their names from the name of the person who originally came and settled in the village. The families in these four pattis belonged to the Aahir community, traditionally cowherds. Besides these four pattis, the village also had some representation from other communities like harijans and other backward classes.

Administrative set-up

Traditionally, the primary decision-making body in the village has been the panchayat. Earlier, the panchayat comprised representatives elected from each patti. Since pattis were based on ancestral lineage, the election of panchayat representative was, by and large, unanimous and without dispute. The sarpanch, the head of the panchayat, has traditionally been the most powerful person in the village. Village elders say that even before the enactment of the 73rd Amendment to the Constitution[1] (which made mandatory the representation of women in panchayat bodies), the Gram Panchayat of Dhanawas has always had a woman representative. But the role of women in terms of actual decision-making and taking up the cause of women in this forum has always been weak. In the normal course, either the husband or the son of the woman member attends the panchayat meetings. The men say this is because the women are not educated and are completely unaware of what is happening in the village. They add that women have enough chores to do and are better left out of activities outside their homes that would essentially eat into the time they can devote to their families. The women, on the other hand, feel that it is the men who are insecure about the women taking on activities that traditionally have been male monopoly. Given the opportunity, women are quite capable of handling both these roles. However, most women say they would rather let things continue as they are than display initiative in this matter and earn the displeasure of the men in their family.

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[1] The 73rd Amendment to the Constitution (and the corresponding legislation in the states), which came into force in 1992, provided statutory status to the Panchayati Raj institutions by designating a clear and significant role to the Gram Panchayats. It also provided one-third reservation for women chairpersons at all the three tiers of panchayat: Gram Panchayat, Panchayat Samiti, and Zila Parishad.

Preparatory work

Establishing rapport

During the process of short-listing the villages, the TERI project team made a number of visits to Dhanawas. At this stage, the project team interacted with the sarpanch and the panchayat, discussing with them the objectives of the project and the purpose of these visits. From the Institute's perspective, this would make the people aware of the potential benefits of such an association and kindle their interest in a joint venture. There were some villagers who saw the relevance of an energy research project in the village. But the majority of the villagers gave the project team a hearing merely because they were curious to know what interest city-bred people had in working in a village. There was also a section of people that showed an interest as they believed that a new subsidy-driven programme would be started in the village, for which the project team was trying to identify beneficiaries. Yet another group of villagers were willing to cooperate with the project team as they hoped TERI would eventually employ some people in its office. The name 'Tata' inflated the expectations of the people.

As part of rapport building, the villagers and TERI staff jointly organized a function, which was also attended by local government officials. Extremely enthusiastic about the affair, the villagers participated in full strength. At the function, TERI's mandate and rationale behind taking up Dhanawas for energy research activities was explained in detail. Future energy options such as biogas, solar energy for household lighting, and energization of pumps were also discussed. It was reiterated that while the primary objective of the Institute would be to carry out research activities, it would be done with a specific focus to develop energy options appropriate for rural applications and those desired by the people. In turn, the village and the panchayat were asked for their support and cooperation to further the Institute's research agenda.

To meet the expectations of the people and to establish rapport with them, TERI during the initial months also assisted the villagers in solving problems that were not essentially related to energy. On one such occasion, some members of the TERI project team accompanied the villagers to the District Commissioner and requested him to sanction the compensation that some villagers whose farms had been destroyed by a hailstorm had applied for. At times, TERI was forced to intervene and resolve village disputes, especially those related to land. This was mainly because the villagers preferred that TERI, considered a neutral party, should arbitrate rather than the panchayat. The Institute was thus able to establish trust and credibility with the people of Dhanawas. The Institute also explored avenues for meeting the non-energy needs of the villagers. For instance, at the request of the villagers, TERI worked out a proposal exploring the possibilities for increasing the depth of a well, which was used primarily by the harijan community for drinking purposes.

Villagers' response

TERI received a largely positive response from the villagers. Firstly, the villagers felt privileged that their village had been selected. Secondly, they were in awe of the Tata name and thought that the village would soon become 'modern', and have facilities comparable to city standards.

The organizational mandate of working on energy alone was a non-issue for most villagers, as was revealed during the initial discussions and the subsequent surveys, and proved to be a limitation for the project team. Convincing certain groups about the relevance of the proposed activities in the light of other development priorities, such as constructing a metal road for the village or opening employment opportunities, was extremely difficult. Conscious efforts were made by the project team to give a correct and balanced picture of what the Institute proposed to do in the village, what it could and could not do, and finally the kind of cooperation and support sought from the villagers. The villagers, however, found it difficult to grasp the relevance and importance of energy research and the benefits that would accrue to them from it. As later discussions with the people revealed, in spite of TERI's efforts, a majority of the villagers from the very beginning understood the event as something that would ultimately lead to increased employment opportunity and development of infrastructure in the village.

Assessment of energy needs and potential of energy projects

The first step in initiating energy projects in the village was to understand the energy supply and consumption patterns. Towards this end, TERI carried out two rounds of detailed energy surveys, the first in 1984 and the second in 1987, both census surveys. These surveys were designed to reflect the local patterns of energy sources and their usage, and quantify the causal relationships between the income and socio-economic status of households and the observed pattern and level of fuel consumption. The second round of survey was carried out to incorporate seasonal variations in consumption patterns and availability of fuels. Local youths were hired from the village and trained to carry out the surveys.

To determine whether scarcity of biomass was an issue of concern to people, the surveys tried to assess the energy needs as perceived by the people. Making demand projections based on the then energy supply and consumption patterns, the surveys also aimed to identify the various renewable energy technologies that had potential in the village.

Energy supply

The fuels used in the village could be broadly classified into non-commercial and commercial fuels. The non-commercial fuels were dung cakes, crop residues (mustard and gwar stalks), and twigs. The commercial fuels used were kerosene, electricity, wood, diesel, and LPG. The non-commercial fuels were obtained from within the village. Sixty-five per cent of the households owned agricultural land from where they procured crop residues. Twigs were collected from the trees growing on agricultural land and from the roadside. A few households also bought wood from a depot in Faroukh Nagar for use as cooking fuel. An estimate of the available biomass resources is given in Table 1. The villagers went to Faroukh Nagar to buy kerosene and to Gurgaon for diesel and LPG.

Table 1 Availability of biomass resources (tonnes) being used as fuel: 1987

Biomass resource	*Annual availability (tonnes)*
Dung	1156
Crop residues	
Mustard	134
Gwar	41
Bajra	40
Wood (farmlands)	11

Source TERI (1994)

About 64% households had electricity connection. However, data collected on the reliability of electricity for lighting showed that power was not available 28% of the time. The monitoring was done between 6 p.m. and 10 p.m., the prime time for electricity use for lighting. The shutdown period varied between 10 and 165 minutes in a day (average shutdown time was more than an hour per day). There was not a single day when uninterrupted power was available. The village did not have street lights.

The energy demand projections showed that the gap between supply and demand of energy for household activities would be around 14% within a period of 10 years and that the village would still depend largely on traditional biomass fuels. At the same time, the demand for energy for agriculture-related activities was estimated to increase by 40% of the present level of consumption.

Energy consumption

The energy consumption pattern of Dhanawas was typical of any village in northern India. The survey showed that 95.50% of the total energy consumed by the households came from traditional fuels, with animal wastes contributing as much as 49.47% and crop residues 42.78%. The share of firewood was 3.25%; kerosene 2.25%; electricity 0.65%; and coal 1.59% (TERI 1984). Animal dung was the main cooking fuel, followed by mustard stalk. A user preference study in the village showed that among the crop residues, mustard stalk was the most preferred fuel for direct burning in traditional chulhas. Mustard, a rabi crop, is usually harvested around the end of February or beginning of March and stored for the rest of the year. The stalk is heaped in piles outside the house. Drying it in monsoons is not difficult as it is lightweight. Since it burns better than dung cakes, it was primarily used for initiating a fire or increasing the flame when required. Mustard stalks were used for making rotis. Gwar stalks were, at times, used as substitutes for mustard stalk. However, their use was limited to times when shortages of mustard stalk were experienced. On the other hand, barley stalks were used for preparing cattle feed while wheat stalks were primarily used as fodder. An assessment of the availability and consumption of mustard stalk in the village showed that large and medium farmers were generally left with large surpluses. To some extent this got distributed among the families that were short of the fuel, mainly the marginal and landless households. It was a common practice in the village to allow the person who harvested the crop to take that part of the mustard stalk harvested by him/her.

The use of firewood in the village was not extensive. It was restricted to only 12 families in the village, a majority of who were landless and had limited access to cow dung and mustard stalk. Firewood, mainly in the form of twigs, was being burnt as fuel. In the form of logs, it accounted for only 1.44% of the total energy consumed per capita. The low consumption of fuelwood was primarily due to high availability of cow dung and mustard stalk, which were collected at seemingly zero monetary cost. Seemingly, because women, the principal gatherers of biomass fuels, had to spend considerable amount of time ensuring fuel supplies for their families. Women from landless or marginal households spent less time in collecting cow dung and crop residues than women from other landholding categories. On the other hand, these women spent more time collecting firewood indicating that landless households had limited access to both cow dung and crop residues (Figure 3).

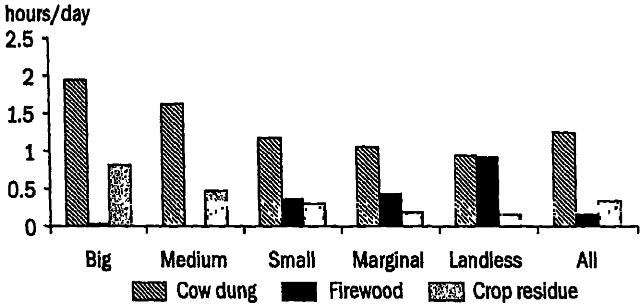

Figure 3 Time spent on collection of biomass fuels (1987)
Source Puri (1988)

Coal was used mainly for heating purposes while electricity and kerosene were primarily used for lighting. The use of coal, kerosene and firewood (especially twigs) was high among small and landless households (Figure 4).

Only three households were found to be using LPG in 1987. Similarly, three farmers in the village were using biogas.

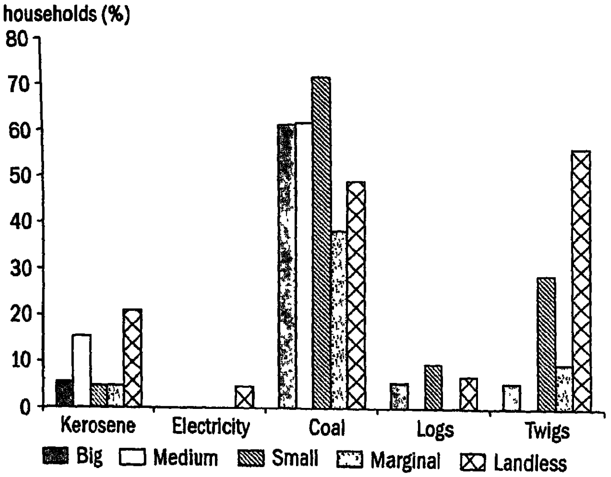

Figure 4 Distribution of households using commercial fuels for cooking (1987)
Source Puri (1988)

Biogas and LPG were mainly used for small cooking tasks such as making tea and cooking vegetables. The service class mainly used commercial fuels like kerosene and fuelwood. Figure 5 gives the per capita monthly household energy consumption, primarily biomass based, according to landholding classification. Biomass fuels have been primarily considered since these provided the bulk of energy consumed for cooking in Dhanawas in the early 1980s.

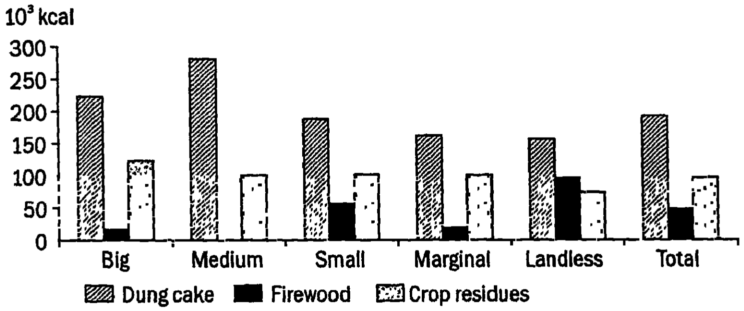

Figure 5 Per capita monthly household energy consumption (10³ kcal) (1987)
Source Puri (1988)

Within the household sector, the main energy consuming activity was cooking, which consumed 79.72% of the total energy. Water heating accounted for 17.84% and lighting less than 3% of the total energy consumed. This break-up remained roughly the same across seasons, though the total quantities consumed of each type of fuel was more in winters. Table 2 gives the monthly household consumption of energy for summer. The percentage of households using different

Table 2 Household consumption of energy for summer (1984)

Fuel	*Unit/month*	*Mcal/month*
Coal/coke (kg)	635	3663.95
Electricity (kWh)	1728	1487.81
Kerosene (litre)	605	5170.94
Crop residues (kg)	28080	98280
Cow dung (kg)	53360	113656.8
Firewood (kg)	1582	7474.95

Note Assumption: The calorific value of the various fuels used in Dhanawas is coal/coke - 5770 kcal/kg; electricity - 861 kcal/kWh; kerosene - 8547 kcal/litre; crop residues - 3500 kcal/kg; cow dung cakes - 2130 kcal/kg; firewood (a) logs - 4750 kcal/kg, (b) twigs - 4700 kcal/kg
Source TERI (1984)

fuels (1987) is shown in Figure 6. Commercial energy for cooking was used by 67% of the rich households (which had an annual income of more than Rs 24 000). In the lowest income group (annual income of less than Rs 6000), only 14.7% households used commercial fuels (TERI 1984).

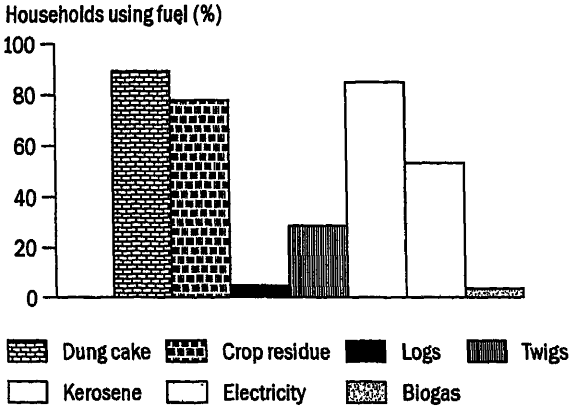

Figure 6 Percentage of households using various fuels (1987)
Source Puri (1988)

The village depended heavily on diesel for water lifting for agriculture. There were 75 electric and 22 diesel pumpsets in the village. Erratic and insufficient power supply and the delay in getting electricity connections (three to four years being the minimum waiting period) forced the villagers to hire diesel engines for water lifting. Kerosene was used for lighting unelectrified households and as a supplementary fuel in the electrified households.

The AIUN survey also established certain important criteria that determine consumption patterns in rural areas. These include resource availability, population, household income, seasonal variations, sociocultural factors, and lifestyles. For example, a significant percentage of households in the landless category was not using mustard stalk as fuel. This was because they had to get the stalk home immediately after harvesting and they could store only limited amounts due to space constraints. Significantly, many families buying fuelwood were landless (Kohli et al. 1992). The use of fuels and quantities consumed also varied with season. For instance, use of wood declined in the rainy season due to non-availability of dry twigs.

Cooking devices A majority of houses in Dhanawas in the early 1980s was made of bricks or stones and very few had a separate kitchen. Most women cooked on the traditional mud chulhas, which were one or two port flueless chulhas. The chulha was kept inside the house or outside, next to the wall. Generally, each house had two mud stoves, one outside and the other inside the house. While the women preferred to cook outside during summers, cooking during winters and the rainy season was done inside the house. Some chulhas were provided with a chimney and were constructed by women from local materials. The main fuels burnt in these chulhas were mustard stalk and dung cakes. These were most suitable for making rotis, the staple food item of the villagers.

The other prominent cooking device being used in the village was called the hara, a traditionally designed special earthen pot for burning sun-dried cattle dung cakes. It was mainly used for slow heating of milk over three to four hours such that, without boiling the milk, the cream separates as a thick layer at the surface. It was also used for cooking fodder for livestock. Two design variations of hara were being used in the village, the portable hara and the fixed or non-portable hara. The households made these themselves. These were mostly located outside the house, generally in the courtyard. The use of hara was extensive with nearly all households having the device. Hara was being used for as many as three to six hours a day in a household consuming 5–9 kg dung cakes (Joshi, Gadhok, and Sengupta 1986).

Another cooking device used by the households was a portable single port mud or metal chulha called uthao, quite popular among the women. The device was normally used for cooking during monsoons. It was an all-purpose device, which could be used for heating water, warming milk, cooking vegetables, etc. Each household in Dhanawas had two if not all of the three traditional chulhas. Hara was a necessary item in the household, while uthao was convenient to use during monsoons due to its portability. The traditional mud stoves were preferred for roti-making.

Energy needs The census surveys established that domestic fuel was not perceived as a problem by a majority of the households. Large and medium farmers faced no shortage at all. The AIUN survey reported that 33% households, mainly belonging to the landless category, experienced fuel shortages in one or more seasons. The problem was particularly acute for the landless families in the labour class who did not own cattle and thus neither had enough dung cakes nor enough money to buy commercial fuels. Landless villagers, who had a reasonably good income from government service or business, mainly managed their requirements with kerosene or commercial fuelwood. Fuel shortages were not faced in summers due to abundant availability of dung cakes and dry twigs. During the rainy and winter seasons, marginal and landless farmers faced major shortages (Kohli et al. 1992). The seasonal availability and use of biomass fuels in Dhanawas in the early 1980s are given in Figure 7.

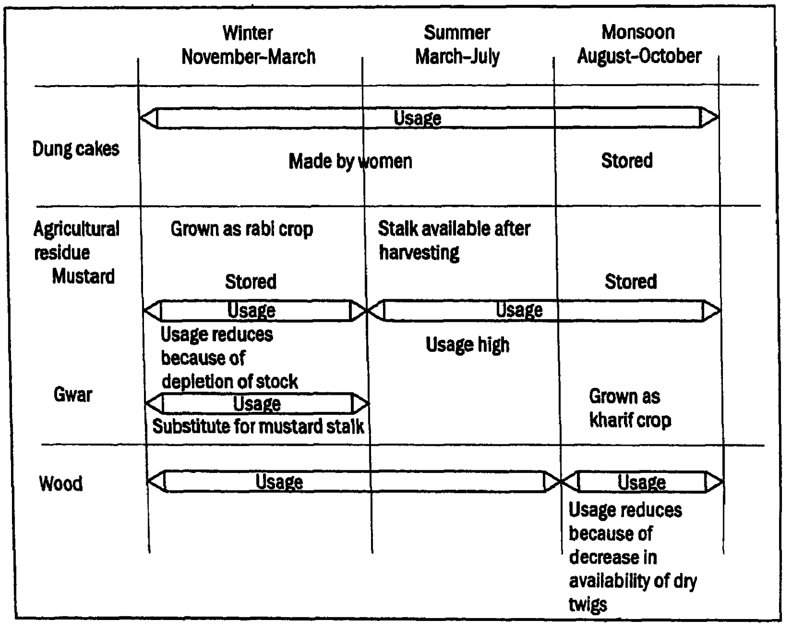

Figure 7 Seasonality in availability and use of biomass fuels

The shortage of electricity was the major energy need perceived by the villagers. They also expressed interest in reducing dung consumption in the hara.

Energy interventions The energy needs were therefore related to energy supply and conservation. Accordingly, the following projects were identified as possibilities for meeting the present and future energy needs of the village.

- *Fuelwood plantation.* The village had about 70 acres of panchayat land, which was unfit for cultivation and was not being used for any purpose. This piece of land, if treated and used for a plantation, could serve as a source of fuelwood as well as fodder and commercial wood for a variety of uses.

- *Improvement of end-use efficiency.* The three ways of improving end-use efficiency considered were (1) introduction of biogas plants as the high livestock population and use of dung as fuel offered great potential; (2) introduction of more efficient chulhas for cooking; and (3) improvement in efficiencies of groundwater pumping.
- *Technical innovations in producing motive power.* Given the growing demand for energy for pumping water for irrigation and the already existing pressures on the rural electrification systems, the demand–supply gap was likely to increase manifold in the future. In this regard, it was proposed that initially one or two wood-based gasifiers would be installed to provide motive power for pumping. It was also expected that in a period of 4–5 years, the cost of PV (photovoltaic) cells would reduce significantly, making it feasible to install a few model PV-based pumpsets for irrigation.
- *Direct solar applications.* Distribution/sale/dissemination of solar cookers to sample households and monitoring the acceptance, use, and performance of the same was decided upon. It was also agreed to explore the possibility of disseminating them on a large scale in the future.

Institution building

For about two years, mainly during the demonstration phase, work was carried out through the sarpanch and some key persons in the village. However, over time, it became apparent that it would be useful to constitute a formal body (from within the village) that could actively participate in the planning and implementation of energy-related activities and then slowly take over the management of energy systems in the village. As this would involve other villagers besides the panchayat, the committee could become more active and remain indifferent to village-level politics to the extent possible. Thus, a VEDC (Village Energy Development Committee) was formed in August 1986 with the written approval of the panchayat. The committee consisted of five members from the village including the sarpanch and one representative from TERI. It was decided by the committee to have at least one person from the harijan community and one elderly person as its members. To deposit money that would be collected from energy activities in the village, a bank account was opened, which was held jointly by a representative from the village and, at the insistence of the villagers, one from the TERI project team. After the first VEDC was constituted and became functional, the members sat together and developed a list of duties and responsibilities for the committee. These were as follows.

1 TERI would carry out activities after consultation with the VEDC.
2 The VEDC would decide on the pricing of energy devices at the recommendation of TERI.
3 Remuneration collected from the village would be spent on village development activities as decided by the committee members, if necessary by seeking the advice of TERI.
4 All the money collected would be deposited in a bank account (jointly with TERI) and spent only after obtaining sanction from the committee.
5 The accounts of the VEDC would be audited at the end of each financial year.
6 The committee would solve problems related to implementation and monitor the activities as and when required.
7 The committee would decide on the place of installation for any device.
8 A minimum of three members from the village and one from TERI would have to be present for any decision to be taken.
9 The VEDC members would be involved in making people aware of TERI's activities and motivating them to adopt the different energy technologies. They were to help TERI in identifying the needs and problems of the villagers so that the extension programmes could be planned accordingly.

Thus, for any activity to be undertaken in the village, details were discussed in the VEDC meetings and members' help sought in implementation. It was also agreed that the minutes

A Village Energy Development Committee meeting in session of the VEDC meeting would be given to the members soon after holding one and not on the day of the next meeting. This would help the members to dwell on the previous discussions held and take appropriate action/decision accordingly.

Changes in the village economy: 1980-99

Over the years, changes in the village economy have directly or indirectly influenced the energy consumption patterns. These include changes in family structure and demography, land ownership, and occupational structure. There have also been changes in the attitudes and aspirations of the people with the increased exposure to urban areas, development of rural markets, education, and the media.

Changes in family structure and demography

An important change was the gradual erosion of the joint family system in favour of nuclear families. As can be seen from Figure 8, between 1987 and 1997, the number of members in an average family reduced by almost one, which is quite significant. It is interesting to note that the quantum of change was the highest among the marginal farmers. A number of them had to break away from joint families because of economic compulsions.

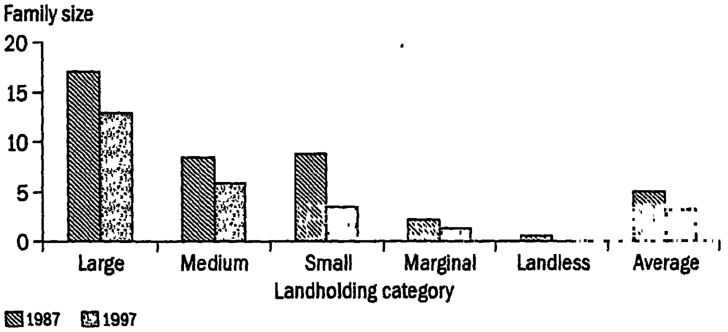

Figure 8 Family size of different landholding categories (1987 and 1997)

Unlike other rural areas, migration from Dhanawas to towns and cities has been negligible. This is attributed to the village's proximity to Gurgaon and Delhi. While a large number of people, especially the younger men, took employment in these two places, Dhanawas did not witness migration of entire families. At the same time, except for girls married into the village, there were no large-scale movements to Dhanawas. As a result, the total population of the village remained more or less stable during the period. Actual data collected by TERI in 1984 and 1995 show that the total population increased only by 2% in this period, while the number of families increased from 127 in 1984 to 144 in 1987 and 189 in 1995, a total increase of 48.8%.

One of the reasons for the population remaining stable was the growing awareness among the people, especially women, regarding family planning measures. Further, as the importance and reliance on occupations other than agriculture increased, so did the need for education. There was an increased emphasis on education for girls and the proportion of girls to boys in the primary school increased over the years (Figure 9).

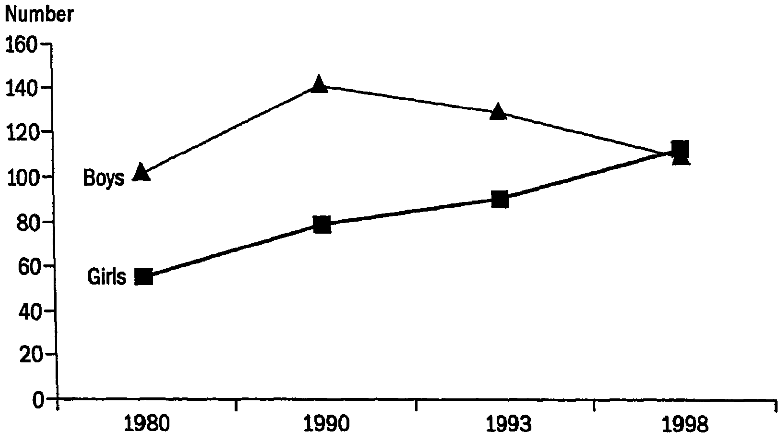

Figure 9 Number of boys and girls in Dhanawas school (1980-98)

Unfortunately, this increased education level among girls did not get translated into a greater decision-making power for them within their families and village society. Even though several women are graduates, they still have little say in the panchayat and in the VEDC.

Better education levels also resulted in girls getting married at a later age. An undesirable, but common phenomenon is a rise in dowries. As boys get more educated, they command higher dowries. On the other hand, an educated girl's parents are required to pay as much dowry for her as for her illiterate sister.

Changes in land ownership

An important development in the last decade or so is the dramatic increase in land prices in and around Gurgaon. Since the early 1990s, there have been proposals to develop this area as an industrial belt. While these proposals never came to fruition, the land prices shot up and land sales increased as never before. Between 1990 and 1997, the price of land in Dhanawas doubled from 25 000–300 000 rupees per acre to 500 000–600 000 rupees per acre. The price at which the land is sold usually depends on the location of the plot. A total of 123 acres of land was sold in Dhanawas between 1990 and 1997. During the same period, the total land purchased by the farmers of Dhanawas was as little as 29 acres. According to the villagers, there were three main reasons for people wanting to make quick gains from selling agricultural land. Firstly, agriculture as an occupation was becoming less remunerative, leading to a fall in the value of land as an asset to hold on to. Some families sold their land in order to find employment for their children by paying bribes and for getting their daughters married (both for dowries and wedding expenses). A majority, however, sold their land to pay off debts. Most of the buyers were outsiders, mainly from Delhi. The land bought was converted into huge farmhouses.

As a result, land available for agriculture is on the decline. It can be seen from Table 3 that the per capita availability of land has been decreasing in all categories of farmers. The per capita land availability for the large landowners declined from 1.77 acres to 1.57 acres (11%) between 1987 and 1997. At the household level, this translates into a reduction in landholding size by almost 25%. The maximum land sales occurred in this category of farmers. During this period, the percentage of farmers in the marginal landholding category increased.

Table 3 Change in landholding pattern between 1987 and 1997

Category of farmers	*Total land (acre)*		*Number of households (%)*		*Cultivable land per household (acre)*		*Per capita cultivable land (acre)*	
	1987	*1997*	*1987*	*1997*	*1987*	*1997*	*1987*	*1997*
Large	308.5	322	19 (16)	25 (13)	17.14	12.88	1.77	1.57
Medium	110.5	112.7	10 (9)	19 (10)	8.5	5.93	1.06	1.02
Small	78.5	79.75	17 (15)	23 (12)	3.74	3.47	0.56	1.63
Marginal	46.75	72.75	16 (14)	53 (28)	2.23	1.37	0.33	0.29
Landless	26	0	54 (46)	69 (37)	0.6	0	0.1	0
All	570.25	586.8	116 (100)	189 (100)	4.88	3.11	0.68	0.55

Source Puri (1988) and field data collected in 1997

Unfortunately, increased earning from sale of land is not being ploughed back as investment for the future. Figure 10

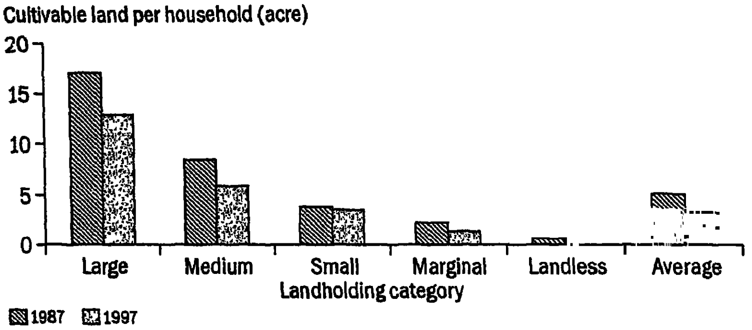

Figure 10 Change in cultivable area per household (1987-97)

shows how the cultivable area per household decreased for different landholding categories in the last decade. While most families in Dhanawas sold at least some part of their land, there was no acquisition of productive assets. Only a handful of farmers, in the older generation, invested the money in purchasing land elsewhere or in assets like tractors and other agricultural implements. A parallel trend has been an increase in consumerism and ostentatious spending. Consumer goods have been flooding the rural markets in the last few years. For a village like Dhanawas, which is not truly rural but peri-urban, the lures are even higher. At the household level, there is an increase in expenditure on consumer durables such as scooters, cars, and television sets. In the 1980s, it was customary to give the bride a cart load of mustard stalk as part of her dowry. This has been replaced by an LPG cylinder, a television, or a radio.

Changes in occupational structure and attitude towards agriculture

The last decade also witnessed a preference among the younger generation to take up jobs outside the village. This was because they feel that agriculture is gradually becoming less remunerative and the only way to have an assured source of income is to have a regular paying job. The trend is to have at least one or two members of the family in government service so that there is a fixed monthly income coming in to support the family. While most families still have some land under cultivation, the importance and dependence on agriculture as a primary source of income is declining. Between 1987 and 1997, the percentage of households in the village with agriculture as the primary source of income declined from 46.5 to 37.2.

During this period, there was a marked increase in earnings and disposable incomes not only in Dhanawas, but also for the state as a whole. Data show that between 1990 and 1993, the percentage of rural households in the lowest income bracket (up to Rs 18 000 per annum) reduced by over 13. The same period saw an increase in the proportion of households in the 'above Rs 78 000' category by almost eight per cent (Table 4).

Table 4 Distribution of households by income groups at 1992/93 prices for Haryana

Annual income (Rs)	*Urban (%)*		*Rural (%)*		*Total (%)*	
	1990	*1993*	*1990*	*1993*	*1990*	*1993*
Up to 18000	32.75	24.16	52.99	39.72	46.83	35.34
18000-36000	42.90	38.02	35.64	31.76	37.85	33.52
36001-56000	18.0	22.58	9.42	14.16	12.04	16.54
56001-78000	4.15	10.61	1.04	6.0	1.99	7.30
Above 78000	2.18	4.62	0.9	8.37	1.24	7.30

Source Rao and Natarajan (1996)

Changes in household energy consumption

An energy survey was conducted between October and December 1997 in Dhanawas to estimate the consumption of various fuels by the households. The sample of 60 respondents included households from all categories of landholding size and those using the various energy devices introduced in the village over the years (biogas plants, improved cookstoves, solar lanterns, etc.). An important objective of this survey was to understand the change in energy consumption pattern that had taken place in the village over the last 10 years.

The survey results show that there has not been a significant change in the energy consumption pattern at the household level over the years. The predominant cooking fuels continue to be dung cakes and agricultural residues.

Use of dung

While both land availability and the cattle holding per capita declined in the 10-year period, the use of dung as fuel actually increased in this period (Figure 11). This is because the dung production from a buffalo (which is the more commonly reared cattle now) is almost one-and-a-half times that from a cow. Secondly, the practice of stall-feeding cattle increased the proportion of dung that could be procured and used as fuel.

There have been two important changes with respect to ownership and composition of cattle over the years (Figure 12).

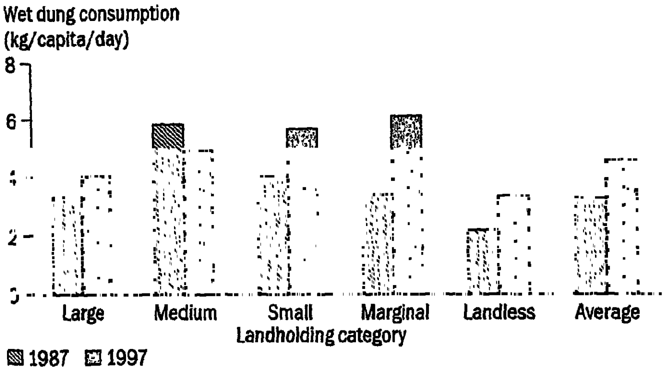

Figure 11 Change in use of animal dung as fuel (1987-97)

Firstly, there has been an overall downward trend in the cattle rearing practice. This has occurred uniformly across all landholding categories, though the extent of decline varies. More importantly, there has been a shift in the preference of farmers from rearing cows to buffaloes.

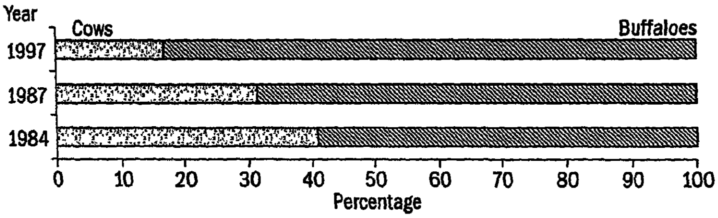

Figure 12 Change in cattle composition (1987-97)

The main reason for the change in cattle composition is that the vast spread of grazing lands and wastelands in the village, where the cattle used to be left for open grazing, are fast diminishing, as land is either being sold or brought under cultivation. As a result, the farmers are forced to rear only those cattle that can be kept tethered in the backyard of the house and stall-fed. As Table 5 shows, this trend has affected the marginal farmers the most and 15% of these farmers no longer own any cattle. According to the villagers, the shift away from open grazing has also affected the agricultural practices adversely. Earlier, cows and goats were left to graze either in the grazing lands or in the agricultural field lying fallow and the dung provided natural organic manure to the plots. The villagers relied entirely on this source of manure

Table 5 Average ownership of cattle heads per household

Category of farmers	No. of adult cattle heads per household		No. of calves per household		Households that do not own cattle (%)	
	1987	*1997*	*1987*	*1997*	*1987*	*1997*
Large	4.83	2.04	1.83	1.56	0	8
Medium	2.62	1.94	1.69	1.42	7.7	0
Small	2.19	1.69	1.38	1.22	0	4
Marginal	1.76	1.09	1.05	0.96	9.5	15
Landless	1.33	1	0.91	0.74	18.6	15
All	2.25	1.34	1.25	1.04	9.5	11

Source Puri (1988) and data collected in 1997

and no chemical fertilizer was applied. To maintain the earlier levels of productivity, farmers have, in recent years, been forced to apply chemical fertilizers in huge quantities.

The practice of rearing goats has disappeared almost completely from the village. Earlier, each family had at least one bullock. But the number of bullocks has now declined. Bullocks were primarily used for ploughing agricultural fields, an activity now virtually undertaken by tractors. Tractors are preferred to bullocks as they are faster, less laborious, and more convenient to handle, and they serve as a means of transportation as well. It is also considered prestigious to own a tractor.

Use of crop residues

While the use of crop residues declined across all categories of landholding sizes, the quantum was highest in the landless category. This is because the practice of paying farm labourers in the form of residues is now on the decline. Further, with the decline in the landholding size, the amount of surplus crop residue available with the large landowners for free distribution also reduced. As a result, the small farmers not only face a shortage as their landholdings have reduced, but they are also deprived of this free source of fuel from the landed farmers (Figure 13).

Use of liquefied petroleum gas

There has been a significant change in the use of LPG. In 1984, when TERI started working in Dhanawas, there was not a single household using LPG for cooking. The number increased to 3 in 1987, 12 in 1994, and 77 in 1999. In spite of the convenience it offers, people use LPG only for specific

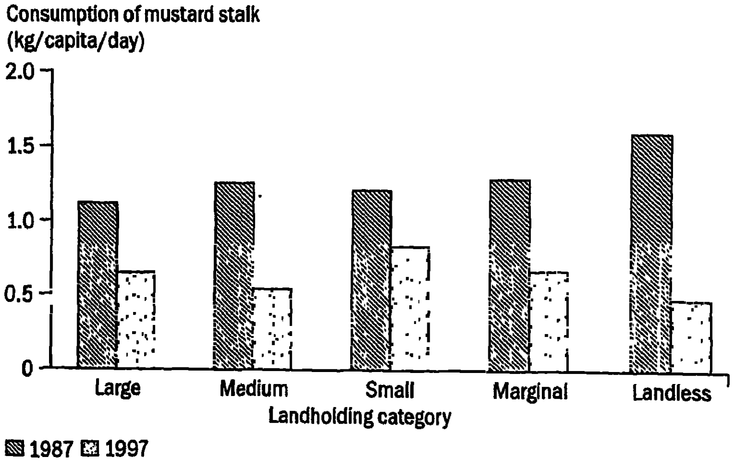

Figure 13 Change in use of mustard stalk as fuel (1987-97)

purposes like making tea or cooking vegetables. For the bulk of cooking tasks, they still rely on biomass fuels, mainly because crop residues and animal dung are still abundantly and freely available. For most families, an LPG cylinder needs to be refilled only once in 2–3 months.

Overall energy consumption pattern

Though commercial fuels have become available in the village, the predominance of biomass fuels has continued. For the village as a whole, there has been a slight decline in the contribution of biomass resources from 97.73% to 90.25% in the 10-year period. The fuels that have caused this decline are LPG and electricity. People have also started using electric heaters for cooking. The increase in kerosene use as compared to other commercial fuels has been negligible.

While there has been a decline in biomass use across the categories, the reasons for this shift vary. In case of the large landholders, villagers ascribe the decline in biomass use to the fact that it is more prestigious to use LPG and electricity for cooking. On the other hand, the reduction in biomass use in the case of marginal and landless households is a result of dwindling landholdings and a shortage of biomass fuels, which were freely available, either from their own fields or from the fields of the large land owners.

Figures 14 and 15 give the share of biomass versus non-biomass fuels in domestic energy (1987 and 1997) and the share of different fuels in domestic energy (1997) respectively.

An analysis of the past trends in Dhanawas indicates that commercial energy sources are making a slow entry into the village. It is expected that these trends are likely to continue

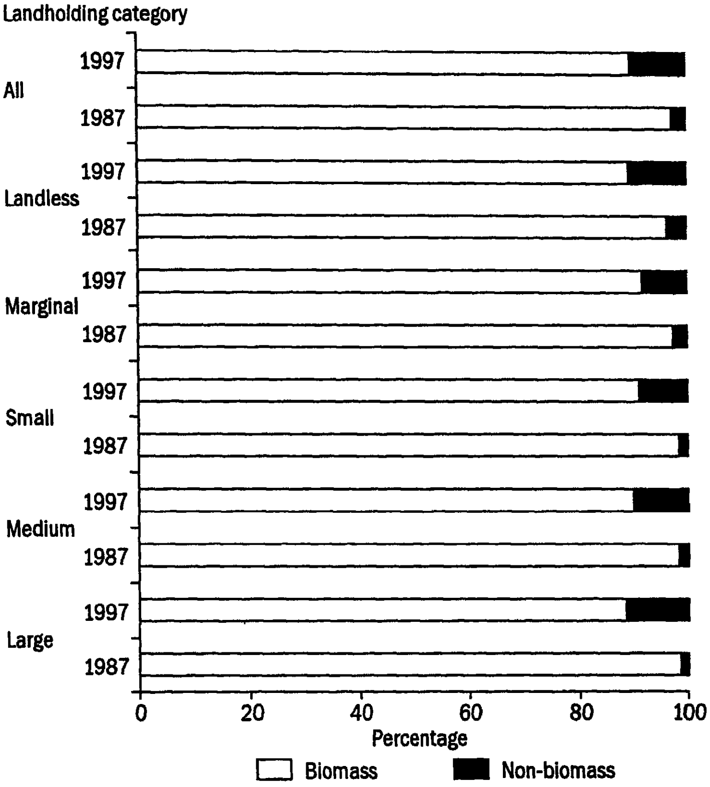

Figure 14 Share of biomass and non-biomass fuels in domestic energy (1987 and 1997)

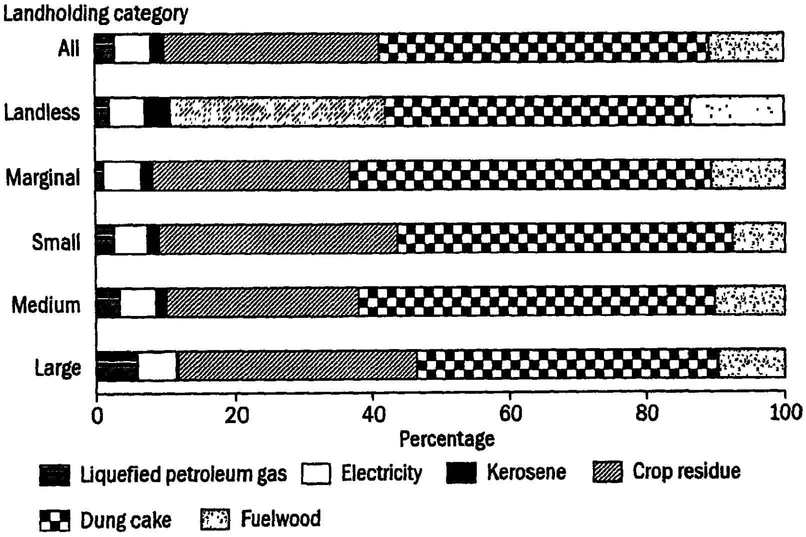

Figure 15 Share of different fuels in domestic energy (1997)

and biomass as a source of energy will play a crucial role in the energy system of Dhanawas in the future as well.

Conclusion

In keeping with the energy usage pattern in rural India, the people of Dhanawas were totally dependent on biomass fuels for meeting most of their energy needs, especially those in the household sector. Energy was not really a priority issue for the entire village. This was especially true for the farmers who had adequate land and cattle. They could get fuel from their own resources or purchase fuel, if required. On the other hand, it was the small landholders and the landless households that really faced a fuel crunch. With time, as changes occurred in the village economy and the younger generation of Dhanawas began to shift away from agriculture as their primary source of income, the energy scenario in the village also shifted to a higher usage of commercial fuels. The shift has, however, not been significant. The poorer sections of the village population find it increasingly difficult to meet their energy needs with the erosion of the traditional practice of sharing the surplus.

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Chapter 4

Cooking energy interventions: the biogas programme

Rural energy matters: the Dhanawas experience 49-61

Identifying cooking energy interventions

The energy surveys having established cooking as the major energy consuming end use in the village, an assessment of possible interventions in the cooking energy system[1] was carried out.

Rural people all over the country were largely dependent on locally available biomass resources that were collected for use, primarily cooking. Energy needs of the people of Dhanawas were, however, location specific and were not representative of all rural areas. As mentioned earlier, a majority of the households in Dhanawas did not perceive availability of fuel to be a problem. This was not only restricted to the perceptions of the villagers, it was also established by an actual assessment of supply of biomass energy. The main fuels, namely cattle dung and crop residues (mustard stalk), were easily available at zero cash cost. These were available in surplus even after consumption as fuel, manure, and fodder. Results of the AIUN survey showed that during the rabi season, that is from November to March, a large quantity of cow dung in the village remained unutilized (Table 1). The TERI team found that this was

Table 1 Availability and consumption of wet cow dung (quintal)[a] for rabi season according to landholding classification

		Consumption			
Category of farmers	*Supply*	*Dung cake*	*Manure*	*Dung cake stored*	*Surplus*
Big	2639.25	920.35	1240.00	324.10	154.80
Medium	1947.50	700.05	900.00	252.15	95.35
Small	1542.75	662.40	500.00	192.60	187.75
Marginal	1224.00	555.60	520.00	212.70	−64.30
Landless	1150.75	1045.30	120.00	178.95	−193.53
All	8504.25	3883.63	3280.00	1160.60	180.07

[a] 1 quintal = 100 kg

Note The availability of cow dung was estimated by a realistic average dung production per animal. Wet dung production per day per cow: 10 kg, per buffalo and per bullock: 15 kg, per calf: 8 kg.

Source Puri (1988)

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[1] The cooking energy system comprises the cookstove, kitchen, fuel, vessel food, and the cook.

because the cattle were taken to the fields for grazing during the summer and monsoon months, and the dung produced at that time was not collected. To meet the winter shortfall, dung cakes were made and stored in structures called bitolas during the summer months. There was no trading of dung in the village and the surplus amount was given free of cost to the needy households. Similarly, big and medium farmers were left with large surpluses of crop residue, which to some extent got distributed among the families that were short of the fuel (Table 2).

Table 2 Availability and consumption of crop residues (in quintal) during the rabi season

	Supply			*Consumption*		*Surplus*	
Category of farmers	*Wheat stalks (1)*	*Mustard stalk (2)*	*Other stalks (gwar and chana) (3)*	*Fuel (4)*	*Cattle feed (5)*	*As fuel (2) – (4)*	*As fodder (1) + (3) – (5)*
Big	1574.72	1299.30	502.00	306.00	84.31	993.30	1992.41
Medium	565.36	340.80	224.99	150.00	51.93	190.80	738.42
Small	425.06	258.44	37.92	201.75	30.00	56.69	432.98
Marginal	330.63	123.54	49.93	211.50	19.54	–87.96	361.02
Landless	189.44	92.30	102.70	285.45	9.43	–193.15	282.66
All	3085.21	2114.38	917.54	1154.70	195.26	959.68	3807.49

Note Straw-grain ratio for mustard - 3.55:1; for wheat - 1.48:1; for barley - 1.58:1
Source Puri (1988)

Two possibilities were thus considered for the village.

1. Encouraging fuel substitution through use of gaseous fuels. Biogas was considered a suitable fuel option that could be made available to the households. This would ensure
   - better use of dung as fuel
   - provide a cleaner fuel for cooking.
2. Introduction of energy-efficient improved cookstoves for fuel saving and better kitchen environment.

In line with the efforts at the national level, the thrust of the Institute was on developing and demonstrating biogas plants and improved cookstoves in the village.

The biogas programme

TERI's initiative in R&D on biogas technology dates back to the early 1980s. The initial work, which was carried out at the Institute's field research unit in Pondicherry, concentrated on modifications in the existing Janata model. The objective was to reduce the structural failures, which were common in Janata model plants. The laboratory model from Pondicherry was shifted for field testing to Dhanawas. In Dhanawas, TERI tried out several design variations of the fixed-dome biogas plant for improving the reliability and functionality of the plant and to optimize the plant design. The main focus of R&D was on (1) improving the functionality and reliability of the plant, (2) reducing the initial cost and installation time, and (3) increasing the gas production rate. A total of 20 plants was constructed in Dhanawas.[2]

Though, during the initial stages, the work on biogas was more R&D oriented, it soon became a full-fledged programme as more households came forward to adopt the technology. The following sections examine the intervention as a programme through its stages of technology development, demonstration, and dissemination. The details of the R&D carried out in the field conditions of Dhanawas are given in Annexure 1.

Groundwork

As discussed before, an energy survey was carried out in the village in 1984. This was done to determine the potential of renewable energy technologies to meet the energy needs of the people. The survey gave information on the existing energy consumption pattern and the resource base available in the village. Using the information collected on cattle ownership and availability of dung, water, and space, a list of potential beneficiaries was drawn up. The TERI project team approached individual households in the list to gauge their level of interest in adopting the technology and to understand the prevalent perceptions regarding biogas. The households were informed that if they agreed to get a biogas plant constructed, they would get a subsidy from TERI. This would be in addition to the government subsidy, and the two together would cover the bulk of the plant cost. The additional subsidy was offered by TERI mainly to kindle the farmer's interest in the programme and motivate them to construct biogas plants. The farmers were also assured that TERI would take the responsibility of ensuring that the plants perform to the satisfaction of the users.

Despite these assurances, none of the households expressed the willingness to install a biogas plant. This was mainly because there had been failures in the past, which had had a negative demonstration effect. Further, the Institute was new to the people. There was also a general lack of appreciation of the benefits of a biogas plant. Most people thought that the system was cumbersome and involved considerable manual labour to operate it. The more well-off farmers felt that they would rather go for an LPG stove; for others, a cleaner fuel from biogas was not worth the investment. There was also resistance to major changes in the traditional cooking practices, particularly in making rotis. Many women preferred a chimney chulha to biogas.

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[2] Based on the final design, which evolved in Dhanawas, TERI installed another 24 plants in Sultanpur, Uttar Pradesh in 1995/96. During 1998/99, 22 plants of the TERI model were constructed in Vellore and 2 in Kanyakumari, Tamil Nadu. In 1999, one plant was constructed in Kumari Kata, Assa[illegible] in, Wardha, Maharashtra.

Demonstration phase

Installing the plants

After several meetings with individual farmers, one farmer agreed to get a plant installed. His positive response resulted more from a 'why not' attitude. The financing of this plant posed some problems as the farmer, in the past, had taken a bank loan and not repaid it; thus he was not eligible for another loan. As it was important for TERI to get the process initiated and demonstrate at least one successful plant in the village, it decided to incur the entire cost of plant construction. The farmer agreed to pay back the amount after he received government subsidy from the Block. However, when the time for payment came, he could not mobilize sufficient cash, which led to disputes with the labourers. The matter was finally resolved by persuading the labourers to accept payment in kind rather than in cash. The plant, which was essentially an improvement over the Janata model, had a capacity of 2 cubic metres and an HRT (hydraulic retention time) of 50 days. It had an additional provision of a stirrer to break the slurry in the dome.

A second biogas plant of the same capacity was constructed in January 1986 with some more modifications. A greenhouse was also attached to the plant to increase gas production in winters. The arrangement, however, was technically non-feasible. But, the gas production rate from the plant was good and soon after commissioning, six more households expressed their willingness to install biogas plants. In the same year, the third biogas plant was constructed in the village. This model had a spherical digester along with an inlet pipe and an outlet tank similar to the previous plant, and a nylon net to break the scum. The modifications introduced were tile plastering for better insulation of the dome and extension of the inlet pipe to the bottom of the dome so that dung in the digester was continuously mixed. Unlike the previous two plants, this plant had an HRT of 40 days.

Initial problems

Some teething problems were experienced in the plants installed during the demonstration phase. Though some of these were related to design, the majority resulted from the fact that the farmers did not always comply with the instructions given to them regarding operation and maintenance. The problem of under-feeding was acute. In one particular case, it was found that though the owner possessed four cattle heads, one or two were always out in the field. Thus, even though the digester temperatures were high, the designed gas production of 2 cubic metres per day was never recorded. A spot check revealed that only about 20 kg cow dung was fed instead of the required 50 kg. Frequent sale of cattle was another reason for under-feeding. Preliminary inquiries revealed that farmers in the village often sold their cattle during the slack season and bought them as and when required. This was because the animals were not required during the non-agricultural season and spending money on fodder was considered a wasteful expenditure. The earlier plants also faced frequent problems of leakage of valves and accumulation of slurry in the pipeline. The women found it difficult to make rotis on the biogas stove. Some improvizations with the burner were attempted, but they did not work out very well.

Apart from these problems, the first plant constructed in the village was abandoned within a year of construction due to its wrong location. The plant had been constructed in the compound of the house that did not have enough space for storing the digested slurry. The slurry thus had to be carried to the place of storage, which was inconvenient. To aggravate the problem, there was a family dispute over the land where the plant was installed. As a result, the household did not bother to carry out even the routine maintenance.

Preparatory phase for large-scale dissemination

Though the first plant was abandoned within a year of construction, it effectively demonstrated the benefits of the technology. In the period 1987/88, three more plants were constructed. These plants were spherical in shape with an HRT of 40 days. These were also provided with a diffuser. The plants were designed such that the inlet slurry went through the diffuser with circular ferrocement plates. The objective was to obtain an effective residence time closer to design HRT.

By this time, the demand for biogas plants was increasing at a rapid pace. People from nearby villages also came to see the functional biogas plants. In response to this, TERI decided to go in for large-scale dissemination. TERI had, until then, been interacting with the panchayat and some other 'key persons' in the village on a case-to-case basis (the VEDC was formed only in August 1986). The panchayat suggested possible beneficiaries, helped TERI to initiate dialogue with potential beneficiaries, and facilitated interactions. The cost and responsibilities of the various stakeholders (the VEDC, panchayat, and TERI) were worked out during this phase. One-third of the total plant cost was borne by TERI. This was in addition to the government subsidy. The household purchased the raw material after receiving the bank loan and TERI paid for labour cost at the time of construction. At the end, TERI and the household shared the net expenditure equally, after deducting the government subsidy from the total cost. The plant owner organized for the cow dung required for initial charging of the plant.

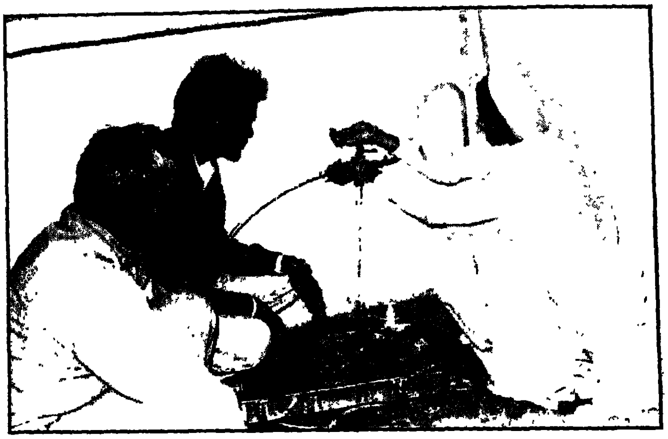
Meanwhile, TERI had also started regular monitoring of the plants that had been constructed. The monitoring was done to assess the performance of the plants in the light of the modifications introduced. Gas flow meters were installed for some of the plants and the household members were taught to take daily readings and maintain a logbook for the same. As an incentive, the household was given Rs 30 per month by TERI. Experiments on slurry rise were also carried out along with measurement of dung fed on a weekly basis.

TERI staff training family members to record data from gas flow meters

In the light of the growing demand for biogas plants, a need to estimate the actual potential of the technology was felt. This was assessed in 1987 through the AIUN survey, which showed that on the basis of the total livestock population of the village, the biogas generation potential in the village was 234 cubic metres per day. Based on a per unit requirement for cooking (340 litres/person-day) and the total adult population (665), the total gas requirement of the village was 226 cubic metres/day, which was within the gas generation capacity. Thus, theoretically, a community biogas plant could meet all the cooking energy requirements of the village. However, this potential came down significantly when the cattle holding per family was considered. Only 51 families had enough cattle heads for a 2-cubic-metre biogas plant. Of these, 76% belonged to the economically well-off category. Most large farmers had enough cattle for a biogas plant. With biogas plants in these 51 households, 173 cubic metres gas could be generated, which constituted 74% of the total village capacity. Of the 51 families, only 6 were willing to have a plant constructed immediately and 5 showed some interest for the future. The rest indicated limitations like space constraints (especially the landless households), lack of manpower for operation and maintenance of the plant, and monetary constraints. The main reason for the lukewarm interest of the people was that most saw no point in investing in a biogas plant as they had easy access and adequate availability of crop residues and animal dung.

Training and capacity building

As the number of biogas plants in the village increased and the likelihood of more households adopting the technology in the future was perceived, the need for training local people in plant construction and the present and potential users in operation and plant maintenance was assessed. A training-cum-installation programme was undertaken wherein masons were given hands-on training in plant construction. TERI gave a one-year guarantee on the plant. After this, the owner was to meet the maintenance expenses, with TERI providing the technical expertise. Efforts were also made to train the masons for routine maintenance jobs. However, it was found that the trained person either did not have the time or the inclination to do the work. Most of the time, the households depended on TERI staff for even minor repairs. Later, the families were convinced of the need for knowing the basics of plant operation and maintenance. Two persons from each user family (a man and a woman) were trained in maintenance and minor repairs.



TERI staff training household women to check gas leakage

Large-scale dissemination

In 1988, the seventh biogas plant was constructed in Dhanawas. This again had a spherical digester with circular ferrocement plates. However, unlike the previous model, an inlet arrangement was provided in which the slurry entered tangentially into a small chamber from where it got deflected. This model had an HRT of 40 days. After constructing four plants of this design, the eleventh plant was constructed in 1991. This again had a tangential inlet, but the ferrocement plate was removed since it was rather inconvenient to install. This design had an HRT of 30 days. Two plants of this design were constructed in Dhanawas. Table 3 gives the details of the variants of the TERI biogas model.

A biogas plant being constructed by trained masons

Table 3 Development of the TERI biogas model

Model	*HRT (days)*	*Shape*	*Inlet*	*Other features*	*Capacity* (m^3/day)	*No. of plants*	*Location*
Mark I	50	Cylindrical	Box	Flat bottom, stirrer	10	1	Varvala
Mark II	50	Cylindrical	Box	Curved bottom, stirrer	2	1	Dhanawas
Mark III	50	Cylindrical	Pipe	Flat bottom, nylon net	2	1	Dhanawas
Mark IV-A	40	Spherical	Pipe	Nylon net	2	1	Dhanawas
Mark IV-B	40	Spherical	Pipe	Diffuser, nylon net	2	2	Dhanawas
					2	1	Berka-Alimuddin
					3	1	Dhanawas
Mark IV-C	40	Spherical	Pipe	Perforated ferrocement plate 30 cm above bottom, mixing tank	2	2	Dhanawas
Mark IV-D (final TERI model)	40	Spherical	Pipe	Tangential inlet, with a deflecting chamber; 60% gas storage, mixing tank	2	2	Dhanawas
					2	24	Sultanpur
Mark V-A	30	Spherical	Pipe	Tangential inlet, with a deflecting chamber; 60% gas storage, mixing tank	2	10	Dhanawas

Source Kishore et al. (1998)

From 1991 onwards, four plants were constructed every year. Of this, two plants were constructed during April–June and two during September–December. The objective of constructing two plants at a time was to reduce costs on transportation and raw material. By this time, both biogas and TERI had become household names in Dhanawas and the villagers began approaching TERI staff directly. The last design variation was tried in 1992. This was similar to the previous one, except that the diameter of the sphere was smaller. Ten plants of this design were constructed in the village. All plants were constructed either in the dhanis (houses in agricultural fields) or at the fringes of the main village. This was mainly due to the limited availability of space for construction of plants.

TERI's continued presence: the impact

Over the years, TERI conducted several training programmes for biogas users to equip them to undertake the routine maintenance and minor repairs. However, while the women took care of cleaning the burner and feeding the plant, by and large, people relied on TERI staff to take care of the repairs. This was because a TERI representative had been living in Dhanawas almost from the beginning, who responded to the villagers' queries and minor problems. This had both positive and negative impacts on the biogas programme in the village. The constant presence and quick response in case of any problem gave the villagers immense faith in the technology, the efficacy of the biogas programme, and the maintenance system. However, the system has become somewhat dependent on the presence of TERI in the village. The households could carry out minor repairs, but only under TERI's supervision.

During the initial years, when the technology was still being developed, TERI's involvement in the biogas programme was very high. The Institute was responsible for practically all the work and played much more than a supervisory role. This included identifying beneficiaries, talking to them, following up on loan and subsidy applications, interacting with block officials, arranging labour, contacting masons, supervising construction, maintenance and repair, etc. Box 1 sums up the responsibilities of TERI and the plant owners.

Box 1 Responsibilities of TERI and plant owners

TERI's role
- continuous supervision of construction
- following up loan and subsidy application forms
- carrying out routine maintenance work
- physical rectification, when required

Plant owners' role
- trench excavation and arrangement of material during construction
- noting down gas flow meter readings (paid by TERI)
- keeping a record of use of biogas and time spent on various cooking tasks

From TERI's perspective, it was important to have a continued presence in the village for several reasons. In the beginning, it was important to instil people's faith in the technology and it was imperative that the plants were constructed well and that they perform satisfactorily. Also, constant monitoring of the plants was required for carrying out further research and to improve the plant design.

Present status

Biogas dissemination in Dhanawas is currently at a stage where the people are fully convinced about the benefits of the technology and that it can work.

Till date, 20 plants have been installed in Dhanawas, of which 18 are functioning satisfactorily. It may be argued that in a village of around 200 households, the impact of 20 biogas plants on the overall energy balance is not significant.

However, it is interesting to note that the rate of acquisition of biogas plants in Dhanawas has been faster than that of LPG gas stoves. The increase in LPG connections between 1987 and 1994 was 12, whereas the increase in number of biogas plants during the same period was 20. Further, most families who own plants prefer to rely entirely on their biogas plant and not use the traditional mud stove, unless absolutely necessary. This, of course, is not always possible for the simple reason that the average family size in Dhanawas is large and most of the biogas plants installed are of 2-cubic-metre capacity; hence the gas produced is inadequate to take care of the entire cooking needs. However, the attitude reflects clearly a high degree of acceptance of the technology.

A recent study carried out by TERI showed that contrary to popular belief, the users of biogas value benefits other than fuel savings and fertilizer production (Malhotra et al. 1998). For example, the women opined that the primary advantage of using biogas over LPG is that it is safe. In rural kitchens, where cooking is done on the floor, if the stove is left unattended, there is always the danger of children playing with it, which can cause serious accidents in the case of LPG stoves. In the case of a biogas stove, even if a child leaves the stove knob in the 'on' position for some time there is no risk of fire by gas leakage or an explosion. There was also significant difference in the perceptions of men and women regarding the advantages of using biogas. For example, the men prioritized the benefits that could bring about monetary savings. Thus, biogas as a source of organic fertilizer was important to them as it could save the use of chemical fertilizers. In households

man cooking on
gas stove

which earlier purchased cooking fuel, the men valued the fuel (hence money) saved. On the other hand, the women attached more importance to benefits like convenience, cleanliness of the kitchen and utensils, and safety.

Limitations to further expansion

Though there are about 15 to 20 families in Dhanawas that have sufficient dung, water, space, and money to install a biogas plant, the scope of constructing more biogas plants seems limited. In recent years, a large number of farmers have sold their land and this trend is likely to grow in the future. In most families, the land is also getting fragmented. On the other hand, very few farmers who have sold their land have bought more land in the village. As a result, there are practically no families in the main village that have adequate space in their yards to construct biogas plants. Families that have their homes in agricultural fields have enough space for construction. However, most of them face the uncertainty of selling their land in the future.

Given these trends, the inclination to invest in a biogas plant is on the decline. This holds good not only for Dhanawas, but for the entire region. While people do think that biogas is a technology very well suited for the villages, the resources necessary for adopting the technology are not there.

Conclusion

The experience in Dhanawas indicates that with proper motivation and institutional and technical support, biogas technology can greatly meet the cooking energy needs of rural people.

Presently, there are 20 households with biogas plants in Dhanawas. A majority of the households in Dhanawas, however, cannot install biogas plants due to reasons such as less/no cattle and lack of space. The limitations of resources, therefore, have to be contended with in view of the socio-economic changes and changes in needs and aspirations of the people.

To promote the technology in rural areas, it is also important to monitor the performance of the system so as to ensure satisfactory functioning under field conditions. Evaluation surveys done in the past give assessments based on percentage of functional/non-functional biogas plants (NCAER 1989 and 1992). However, this does not give a true picture of the performance of the plants in the field. Plants need to be monitored to understand variations in gas production, gas consumption, and dung input. Experiences in Dhanawas show that continuous monitoring of plant performance is essential for further design improvements making it suitable under field conditions. Gas production needs to be monitored for a minimum of one year to overcome the variation of the gas production rate due to seasonal change. This will also take into account the time lag between the change in cattle dung charge rate and rate in gas production.

Another important lesson from the programme has been that, to make biogas technology popular in rural areas, a strong maintenance and back-up service is crucial. This is especially required when the confidence levels of the people in the technology are low and there is a general resistance to adopt the technology. This happens under two conditions (1) in cases where the technology is relatively new to the people or (2) where the people are unwilling to install plants due to unfavourable past experiences. The continuous presence of the implementing agency in the initial stages goes a long way in building the confidence of the people.

In the larger context, the Dhanawas experience illustrates the potential of making biogas a viable option for meeting the cooking energy needs in rural areas. This is particularly of relevance to states where a large portion of household energy needs are being met through animal dung.

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Chapter 5

Cooking energy interventions: the improved chulha programme

Rural energy matters: the Dhanawas experience 63–80

When TERI started working in Dhanawas in 1984, three types of chulha were in use in the village. These were hara, uthao, and the traditional mud stove. Each household had at least two, if not all, of these three traditional chulhas. As mentioned earlier, most households in Dhanawas used hara for 3–6 hours every day consuming approximately 5–9 kg dung cakes. Uthao was widely used in monsoons. It was an all-purpose stove used for heating water, warming milk, cooking vegetables, making tea, etc. Besides these two stoves, a two-port or one-port mud chulha was commonly found in the kitchens. Some of them were also provided with a chimney and were found to be most suitable for making rotis, the staple food item of the villagers. The women constructed these mud stoves.

Selection of the improved chulha

Apart from the biogas cookstoves, TERI considered improved chulhas an appropriate intervention for energy conservation. The main objectives of the improved chulha programme in Dhanawas were to disseminate and monitor improved chulhas and to study their field performance and their impact on household energy consumption pattern and cooking practices. The technical experiments carried out by TERI on improved chulhas are described in Annexure 2.

TERI disseminated two kinds of improved stoves in the village (1) TARA, a single-port flueless metal stove as a replacement of uthao, and (2) Nada, a two-port improved stove with chimney.

Initially, two models of improved single-port chulhas, Shanti (mud) and TARA (metal), were tested and compared with the traditional chulha by making rotis on them. Since both the chulhas would be used mainly outdoors, reduction in smoke emission was not used as a criterion for selecting the chulha. The tests showed that while Shanti consumed more fuel, TARA was unsuitable for making rotis and took a longer time than the traditional cookstove. However, in the light of the fact that it could save substantial energy in other operations, it was decided to demonstrate TARA as a replacement to uthao.

Dissemination strategy

The strategy adopted by TERI for disseminating the improved chulhas broadly consisted of

1 creating an awareness in the village about improved chulhas and their benefits
2 demonstrating the improved chulhas on a small scale
3 monitoring their performance and problems faced in usage, and identifying problems of compatibility of new chulhas with the existing cooking energy system
4 fixing the price and finalizing the dissemination methodology with the VEDC
5 disseminating on a large scale
6 monitoring and evaluating the cooking energy system with improved chulhas against the traditional cooking energy system. The evaluation parameters included compatibility with cooking practices, fuel consumption, and users' perceptions.

Dissemination of TARA chulhas

Demonstration phase

During the summer of 1986, TARA chulhas were given to four households in the village for demonstration. The households used these for a few months during and after which their feedback on the performance of the chulhas was collected. The feedback obtained was largely positive. The users said the improved chulha saved fuel and time, and emitted less smoke than the traditional uthao. However, the chulha was found unsuitable for cooking rotis.

Dissemination phase

The overall response being encouraging, the VEDC decided to go ahead with the dissemination of the TARA chulhas. To enable more families to adopt the chulha, the price was subsidized and fixed at Rs 15 per chulha. The chulhas were handed over to the VEDC members for distribution. There was no restriction on the number of chulhas to be distributed and anyone could get it if they paid for it. It was also decided that the chulhas would be given only to the inhabitants of Dhanawas and not to any outsiders. A pamphlet explaining the usage of the chulha was prepared in Hindi and distributed along with the cookstove.

Initially, the people were keen to use the new device and a total of 136 chulhas were sold within a year. Seventy-four per cent households in the village bought the chulhas. Its adoption in the service class was much higher (73% of the total households in this class) than in any other category of households. The primary reason that made the chulha popular with the women was that it was quite similar to the traditional chulha, which they were accustomed to. The keenness also resulted from the desire to use a new device. The money collected was deposited in the committee account.

Between 1986 and 1989, a majority of the households in the village had bought the chulha and by 1988/89 the programme was phased out.

Performance of the chulhas

The first round of survey of the TARA chulhas was carried out in September 1986, a month after their dissemination. The objective of this survey was to assess their usage pattern in terms of reasons for purchase, frequency of use, fuels used, food cooked, perceptions on fuel and time saving, and problems faced in usage. The survey found that a majority of the households (65%) had purchased TARA stove because it was portable, while time- and fuel-saving were the deciding factors for the remaining 35% households. Though it was being used regularly by most households (73%), its use was mostly limited to heating milk, preparing tea, and cooking vegetables. The main usage-related problems faced were that

- it was unsuitable for making rotis
- ash fell on the ground and blackened the floor
- stove got very hot
- pots became black
- flames leapt through the sides
- grate kept wobbling
- wood had to be chopped into small pieces.

The first survey of chulhas was followed by an in-depth evaluation of the chulha programme in December 1987 (Kohli et al. 1992). In this survey, the following were determined.

1 number of households still having the chulha
2 working condition of the chulhas
3 frequency of use
4 ownership/use of other portable chulhas
5 problems faced in usage.

The survey showed that of the 68 households that had purchased the chulha, 52 still had them. Of these, three were not using them as they did not like them (reasons not specified) and four used them only in the rainy season. While most users seemed satisfied on accounts of the fuel- and time-saving benefits, they also identified some drawbacks in the model. The main complaint was the inability to make rotis. Some users also felt that it was too small and could accommodate very little fuel at a time. The survey showed that most households used TARA chulhas for making tea and cooking vegetables, while the bulk of cooking continued to be done on the traditional mud stove. What was surprising was that in spite of the drawbacks, as many as 77% users were satisfied with the performance of the chulha. The reasons for satisfaction and dissatisfaction with TARA chulhas are given in Table 1.

Table 1 Reasons for satisfaction and dissatisfaction with TARA chulhas

Reasons for satisfaction	*No. of households*	*Reasons for dissatisfaction*	*No. of households*
Consumes less fuel	29	Cannot make rotis	11
Gives out less smoke	13	Too small	3
Takes less time	25	Gets too hot	4
		Ash spreads on the floor	3
		Blackens the vessel more	2
		Not suitable for burning dung cakes	1

Another evaluation survey was carried out in July 1988 to examine the condition of the chulhas. The survey findings showed that 45% of the chulhas were in good condition. Also, though none of the respondents were willing to buy a replacement, 10 of them were interested in buying metal chulhas that could make rotis. After 18 months of distribution, only half the chulhas disseminated were found in use. In some large families, where the chulhas had been used extensively, they had worn out in less than a year's time. In the light of the fact that the users were facing several problems in usage and also that the then-existing demand had been fulfilled, it was decided to discontinue the TARA chulha programme in 1989.

Dissemination of Nada chulhas

Around the same time, Nada chulhas were also promoted in the village. The Nada model is a fixed two-port mud stove, with a chimney. It was considered as a possible alternative to the traditional mud stove. The chulha was promoted as a smoke-removing device, since fuel saving was not a priority of the villagers.

The main reason for selecting this model was that it had been in use in several states for a few years and had become popular among the rural users. An additional advantage of going in for this particular model was that it already had a well worked out dissemination strategy.[1] The HSWRC, Khori had been promoting Nada chulhas in Mohindergarh district, Haryana since 1985 and the programme had been well received. The Nada chulha dissemination strategy had five major programme components.

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[1] The Nada chulha was developed in 1980 by a woman of Nada village in Haryana. It was a simple modification of her traditional two-port chulha to which a chimney was attached. The chulha's design was refined and a dissemination methodology was worked out over a period of two years with financial assistance from SIDA (Swedish International Development Agency). Under this, local women were trained as stove builders (chulha mistris) as they are best suited to transfer a new technology to other women.

1. Training of local village women as chulha mistris. This includes selection, training, and post-training support and supervision.
2. Each mistri is paid a wage for building chulhas and a monthly honorarium for follow-up. User education is part of the job.
3. All users pay a subsidized price for the chulha.
4. All mistris and supervisors were required to attend monthly meetings where problems and progress are discussed.
5. Supply and delivery of materials is the responsibility of the organization (Sarin 1987).

TERI's decision to promote the same model was strengthened by the fact that the lifestyles and the food habits of the people of Mohindergarh and Gurgaon districts were similar. Thus it was expected that the Nada chulha model would be appropriate for this region as well.

Technology demonstration

As the initial step, TERI staff was trained at the HSWRC to familiarize them with the technology and also with the process of technology transfer.

Demonstration

During September 1986, 10 chulhas were installed free of cost for demonstration. All the chulhas were installed inside the kitchen/house so that they could be saved from wear and tear caused by exposure to unfavourable weather conditions. Constructing the chulhas inside was also expected to maximize the impact of the chulhas as smoke-reducing devices.

Initially, none of the households showed any interest in installing the new chulha. With great persuasion 10 households were convinced to get the chulhas installed. Finding the right kind of houses for construction of chulhas was also a problem because of the following reasons.

- At that time, very few houses had separate kitchens where the chulha could be installed.
- It was difficult to convince willing households that had stone or lintel roofs to break the roof in order to introduce a hole for the chimney.

The stoves for demonstration were constructed by a team of women staff from the HSWRC under the supervision of SAHAJ (one of the NGO groups that had been actively spite of the drawbacks, as many as 77% users were satisfied with the performance of the chulha. The reasons for satisfaction and dissatisfaction with TARA chulhas are given in Table 1.

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- At that time, very few houses had separate kitchens where the chulha could be installed.
- It was difficult to convince willing households that had stone or lintel roofs to break the roof in order to introduce a hole for the chimney.

The stoves for demonstration were constructed by a team of women staff from the HSWRC under the supervision of SAHAJ (one of the NGO groups that had been actively involved in the dissemination of Nada chulhas) during September–October 1986. The construction material such as mud, dung, and wheat straw was arranged by the household. TERI bore the cost of material (AC pipes, chimney damper, metal strips, and cowls), while the household was responsible for plastering the gap between chimney and roof.

Of the ten chulhas installed, three were in houses with thatched roof and two had a hara attached to the chulha. Instead of front dampers, the chulhas had chimney dampers; the position of the fire door was perpendicular or parallel to the tunnel depending on the place available in the kitchen and the cook's sitting position.

To familiarize the users with the chulhas, a write-up was provided to the household, explaining the use and maintenance of Nada chulhas. A poster explaining the use of the chulha was also put up in the kitchens.

To ensure their proper use and to rectify problems, TERI carried out weekly monitoring of the chulhas. This included tests on fuel consumption and thermal performance. The immediate feedback (within one month of construction) was that most people preferred to cook outside in summers; hence, a majority of the chulhas were not being used. The women complained of smoke escaping from the sides of the

Sharing information with women on the improved chulha first pothole and that not enough heat passed to the second pothole. The women were reluctant to use the dampers. Also, some women kept the second pothole open while cooking on the first one, thus allowing the heat to escape.

Response of the users

The attitude of the villagers changed gradually and in a few months, a large number of households showed interest in acquiring Nada chulhas.

A very mixed feedback regarding fuel and time saved by Nada chulhas was received from the users. Some users had already modified their chulha by increasing the inner diameter of the first pothole. Other problems reported by the users included

- smoke escapes from the sides of the first pothole
- first pothole is small in size: bigger vessels do not fit
- not enough heat passes to the second pothole
- roti gets black with soot when grilled in the firebox door
- consumes more fuel than the traditional mud stove.

A more favourable feedback was received from the AIUN survey carried out in March 1987. With respect to Nada chulhas, the survey aimed to (1) assess the perception of users on the performance of Nada chulha and (2) identify households interested in acquiring Nada chulhas and receiving training. The survey showed that out of ten chulhas installed, eight were in use. The users were satisfied with the chulha mainly on account of reduction of smoke levels in the kitchen. However, there was no reduction in fuel consumption vis-a-vis the traditional chulha. As the women preferred to cook in the open during summers, the Nada chulha was used mainly in winters and the rainy season. The response of households where the Nada chulhas had not been installed was also quite favourable. Among households that had a kitchen, 43 expressed willingness to have Nada chulhas installed in their homes, 13 of which belonged to economically weaker section. Twenty-three households were not interested in having it installed as they were not convinced of its benefits. Among the economically weaker sections, the willingness to install chulhas was high; however, not having separate kitchens in their houses was a major constraint for most.

Capacity building in chulha construction

Quite a few women showed an interest in receiving training to construct Nada chulhas. However, it was restricted to those willing to construct chulhas in other households, with preference given to women in need of money. To ensure continued participation and also to attract more women trainees, the VEDC

A woman trainee constructing an improved chulha under supervision of TERI staff

suggested that the women be given some monetary incentive to participate in the training course. Accordingly, a stipend of Rs 100 per participant was fixed – Rs 75 was to be paid at the end of the course and the balance was to be given after the trainee had constructed a minimum of three chulhas. It was clarified that the objective of giving training in chulha construction was to develop skills that may help the trainees in getting some additional income.

The SAHAJ and TERI teams conducted the training. The training programme was held in the village for a period of two weeks. At the end of the training programme, TERI distributed the remaining AC pipes, chimney dampers, metal strips, etc., among the trainees so that they could make chulhas in their own homes. Within a week of completion of the training programme, each participant had constructed a chulha in her house. Upon checking the chulhas, it was found that most had made mistakes in making the tunnel between the two potholes and the baffle. These were rectified under the supervision of TERI staff.

Dissemination through the chulha mistris

The trained chulha mistris constructed chulhas in other households under the supervision of TERI staff during September and October 1987. The chulha mistris were also responsible for motivating the households. The household paid Rs 22 towards half the cost of the chimney pipes and part of the labour cost. The chulha mistri was paid Rs 10 for each chulha installed. TERI bore the cost of other material and the remaining chimney cost, which worked out to be about Rs 43 per chulha. The money paid by the household was deposited in the VEDC's account.

At this stage, the VEDC decided that as the task of constructing the chulhas was supervised by TERI and the construction was carried out by the mistri, the villagers should directly approach TERI instead of approaching the VEDC. It was also felt that as most of the VEDC members were men, the women may hesitate to approach them if they had some queries or doubts. Again, as there was no restriction on the number of chulhas that could be constructed in a household, distribution was not an issue.

After each trainee had constructed three chulhas, she built chulhas in other households. TERI only provided the material and checked the stove after it was constructed. Around 65 stoves were constructed in the village by the end of December 1987. By this time, 44% households had adopted the Nada chulha. All the households that constructed Nada chulhas were the ones that had purchased the portable TARA chulha. Acceptance of Nada chulha was highest (51%) among households that were completely dependent on agriculture, and lowest among households in the service category.

Maintenance, monitoring, and evaluation

The Nada chulhas were periodically assessed for their thermal performance, usage, and impact on cooking energy consumption. Four chulha mistris were selected (based on their interest and readiness to attend to chulhas) to visit the installed chulhas every week to inspect if they were being properly used and to advise the cook if she had any problems. It was the mistri's responsibility to rectify the problems as and when they occurred. The chulha mistri was required to check

- the fitting between pots and ports for gaps
- the tunnel for blockage or widening
- the baffle for reduction in its height and change in its shape.

She also had to check whether (1) the chimney damper was used properly, (2) the chimney was cleaned, and (3) the chulha was coated regularly. The mistri received a payment of Rs 5 per chulha per month.

Each newly constructed chulha was monitored for four months. After a few weeks, the mistris lost interest in monitoring and had to be persuaded by the field staff to make the visits. The mistris felt that their work would not be required once the demand within the village was fulfilled. None of them were comfortable with the idea of constructing chulhas in other villages.

Performance of the chulhas

An evaluation of the improved chulha programme was carried out in the village in 1990, three years after the programme was introduced (Kukrety et al. 1990). The objectives of the survey were (1) to assess the demand for improved chulhas in Dhanawas, and (2) to determine the scope of extending the programme to other villages. The sample covered in the survey included respondents who were presently using improved chulhas (20%), those who used it for some time before discarding it (24%), and those who never had improved chulhas (56%). Some of the salient findings of the survey were as follows.

Usage and perceived benefits of improved chulhas

Among the households that were still using improved chulhas, 47% were using it for all their cooking requirements while the others used both the traditional and the improved chulha for cooking. By and large, most people preferred to cook vegetables, make tea, and boil water on the improved chulha. The households continued to use their traditional cookstove to make rotis. Though the improved chulhas were admired for their capacity to reduce smoke, they were not considered to be as safe as the traditional cookstove.

Seasonal variation in use of improved chulhas

About 80% of the users used the improved chulhas throughout the year. The others used the improved cookstove during winter and monsoons when indoor cooking became comfortable.

Condition of the chulhas

After three years, 40% improved chulhas were found to be in good working condition, another 40% required minor repairs like mud coating, 13% chulhas required renovation, and 7% required rebuilding (these were the oldest chulhas). Among problems faced by the users was that the chimneys were not sturdy enough, the dampers corroded rapidly (as they were made of a thin iron sheet), and the potholes became smaller with repeated coatings of mud.

Reasons for discontinuing with the use of improved chulhas

The major reason for discarding the Nada chulha was that there had been considerable wear and tear during rains. Some of the households had stopped using them as they constructed new (pucca) houses. Some others had acquired LPG stoves and had stopped using the older devices, which were now considered inconvenient and antiquated.

Reasons for not installing improved chulhas

The main reason villagers did not adopt the improved chulha was that they did not have separate kitchens and therefore cooked either outside or in the house depending on the weather. As the improved chulha had to be fixed in some place, they chose not to go for it.

Based on the results of the survey, the study concluded that there was potential of introducing more chulhas in the village, however on a small scale. The limiting factor in taking up a large-scale programme in the village was that a majority of the households did not have separate kitchens. At the same time, a large number of families were constructing pucca houses and it was expected that these households could be the target group for improved chulhas in the future. Thus, it was decided to wait for a year or two before the next phase of the improved chulha programme could be initiated in the village.

Phasing out

Before the programme was phased out, another training programme was conducted in the village to train more women to construct Nada chulhas in their homes. The need arose because (1) a majority of the chulha mistris who were trained earlier were unwilling to construct chulhas in other households; (2) a few had got married out of the village; and (3) the demand for improved chulhas was on the rise again as people were constructing pucca houses. TERI staff conducted the training programme, which lasted a week. Following the training programme, 22 chulhas were constructed by these trained mistris. A majority of the trained women constructed chulhas only in their households. Soon afterwards, another batch of 18 women was trained to construct the Nada chulha.

The different phases in the chulha dissemination programme in Dhanawas are given in Table 2 in a chronological order.

Table 2 Dissemination of Nada chulhas

Phase	*Year*	*No. of chulhas installed*
Information dissemination	June 1986	
Discussions and survey	September-October 1986	
- potential assessment of Nada chulhas		
- selection of beneficiaries for demonstration		
Demonstration and collection of user feedback	October 1986	10
Training of chulha mistris	June 1987	
Dissemination and monitoring	1988/89	55
Second round of dissemination	1990/91	22
Training of chulha mistris	October 1991	
Training of chulha mistris	July-September 1992	18
Third round of dissemination	May 1995	10
Total		115

Box 1 summarizes the roles of TERI and the villagers in the improved chulha programme in Dhanawas.

Box 1 Roles of TERI and the villagers

Role of TERI

1 Information dissemination: providing information to women on technology through brochures, manuals, discussions, demonstrations
2 Management and coordination: arranging material for building NADA chulha, selection of beneficiaries, coordinating with outside experts in chulha construction, arranging meetings on cost sharing with village committee
3 Training: selecting trainees, conducting programmes, follow-ups
4 Supervision: supervising the installation of chulhas in the village by local women
5 Extension: identifying potential beneficiary households, holding discussions
6 Monitoring: regular monitoring of chulhas to identify problems, assess users' satisfaction

Role of villagers

1 Village committee: identifying beneficiaries, managing finances
2 Village women: constructing chulhas, doing repairs, providing feedback
3 Beneficiary households: arranging for raw material, making monetary contributions

Dissemination of cement chulhas

As mentioned before, the main problem with the Nada chulha was its short life. Once the villagers constructed pucca houses, the demand for cement chulhas grew. They were willing to pay a higher price for the chulha, but wanted a durable and aesthetically superior device. In response to this, 20 improved cemented chulhas were constructed in the village during March–April 1997. These chulhas are constructed with tile, cement, and sand and have two potholes and cement pipes. The advantages of the cement chulhas are that they are

A woman cooking on an improved cement chulha portable, last longer, do not require routine maintenance like clay coating, and do not risk damage from rain. The cost of these chulhas is Rs 145. Of the total cost, the beneficiary contribution was Rs 110 (Rs 50 towards chulha material and Rs 60 towards asbestos cement pipes for chimney). TERI contributed Rs 35 per chulha.

essons learnt

The strategy that was adopted for development, demonstration, and dissemination of improved chulhas in Dhanawas provided valuable lessons.

1 The experience highlights the importance of field testing before the large-scale dissemination of any model of improved chulha. Field testing not only helps in assessing the efficiency gains, but more importantly helps in assessing the needs and preferences of the prospective users, and arriving at a design that will suit their requirements. A proven technology with a history of field trials may still require certain modifications so as to fit in the local situation. The complex cooking energy system in Dhanawas is an example of very region- and culture-specific cooking energy system in India. In this situation, the role of improved cooking stoves needs to be examined carefully. In Dhanawas, this implied knowing how much time people cook within and outside the house during different seasons of the year, what is cooked outside, what is cooked inside, etc.

2 The users' perception of the benefits of a technology determines the rate of adoption. For instance, a survey of user households of TARA chulha after 18 months of dissemination in Dhanawas showed that about 65% households purchased them because of their portability, while time- and fuel-saving were the deciding factors for 35% households. Similarly, the most appreciated feature of the NADA chulha was its ability to remove smoke.

3 While facilitating the participation of women in such programmes, it is important to define the kind and extent of women's involvement that can be obtained within the existing social structure. A majority of the women trained in chulha construction were not ready to go to other households to construct chulhas. This necessitated the training of women from almost all user households.

4 The chulhas made by local women showed that the quality control required to achieve reliable fuel saving is difficult to maintain. This was true in the case of Dhanawas where tests conducted on chulhas constructed by the trained village women showed significant variations in measurements and consequently in efficiencies.

Conclusion

An assessment of the strategies adopted in the planning and implementation of biogas and improved chulha programmes in Dhanawas has provided some valuable insights into aspects of policy-making, planning, and implementation of household energy programmes.

Assessment of targets

In Dhanawas, targets were decided based on careful assessment studies that, among other factors (such as the availability of dung, water, and space in case of biogas), determined the willingness of individual households to adopt the technology. In the case of biogas, a demand was created based on successful technology demonstration. The targets were subsequently revised in the light of the changes in socio-economic conditions and the aspirations of the people. What emerges is the need for targets to flow from bottom to top. At what stage of the programme should the targets be determined also needs to be identified. For instance, in an area where the technology is relatively new or unheard of, targets need to be determined after the people are made fully aware of the technology, its benefits, and the programme. Thus, planning needs to be done at a decentralized level and the targets need to be revised on a regular basis.

Selection of site for demonstration

Animal dung and mustard stalk continue to be the predominant fuels for cooking in Dhanawas. This shows that the programmes have not been able to make a significant impact on the village energy scenario. The reasons for this have been pointed out earlier. But, from the programme planning perspective, installing improved chulhas in a village where scarcity of biomass was never a problem was not appropriate especially when the objective was technology demonstration. This is true even at the level of the national programmes. The NPIC, for instance, was conceived as a demonstration programme. However, no effort was made to find areas experiencing shortages in fuelwood where the chances of the programme being successful were high. Such areas could have served as excellent demonstration sites.

Suitability of technology

For a technological programme to succeed anywhere, it should be suitable to the area. Suitability should take into account both technical feasibility and the local lifestyles and traditional systems. In the current programmes, 'suitability' is not examined carefully. This is probably because the targets flow from top to bottom rather than the other way around. The potential of technologies such as biogas continues to be based on dung availability which does not give a true picture.

In Dhanawas, there was enormous potential to conserve biomass and provide a clean and cheap source of energy to a majority of the households – 50% households had enough cattle dung to have a family-size biogas plant; 76% of these belonged to the economically well-off category. However, almost 47.5% of the households having enough cattle heads were not willing to have a plant due to lack of sufficient space for construction. It was a ruling factor particularly for the landless households. Further, lack of manpower for the operation and maintenance of plants, economic constraints, easy and adequate supply of crop residues as fuels, and resistance to adopt a new technology were some other reasons for the unwillingness to construct plants. Hence, there was a need for demonstrating a functional biogas plant to reduce uncertainty, providing adequate maintenance support at the doorstep, and giving warranty for trouble-free operation before setting targets and going for wide-scale dissemination.

Technologies will also have to be modified to make them suitable to the existing local conditions. The standard procedure of implementing technologies as they exist leads to poor acceptance and failures. In Dhanawas, a modified Janata model was initially introduced and plant models were continually improved for reducing cost and improving performance. After several design changes and after constructing about 10 biogas plants, a final plant design (spherical type) was achieved. This was a significant improvement over the existing fixed-dome biogas models.

Programme flexibility

The programme has to be modified to incorporate changes in the socio-economic conditions of the local people. In the case of Dhanawas, as the quality of life improved and people started moving into concrete houses, a change in the type of cookstove was demanded. TERI adequately responded to the need by introducing improved cement chulhas.

The main strength of TERI's chulha programme was that it was monitored continuously and was flexible enough to accommodate the results from such assessments. The NPIC approved a number of chulha models as eligible for subsidy under the programme. These models were developed keeping in mind the regional complexities in fuel usage patterns, cooking practices, and eating habits. Yet, the programme does not incorporate any mechanism whereby, before dissemination, a pilot-scale testing can be carried out to actually affirm the suitability of the model.

The current mode of evaluating programmes does not provide inputs to modifying the programme strategy. The evaluations are seldom used at the district/block levels to assess further scope for dissemination of the technologies in the area. These evaluations should be used to help in taking decisions relating to the scale of programme extension, time for execution, and feasibility for replication.

Incorporating a role for women

The importance of women's role in the design and dissemination of cooking energy devices cannot be overemphasized. As women are the principal users of chulhas, their preference and convenience should be the deciding factors in any chulha design. A model that increases their already high workload or is cumbersome to use is not likely to be accepted by them. The TARA chulha disseminated in Dhanawas was rejected by women mainly because it was unsuitable for making rotis and forced them to chop firewood into small pieces and clean the ash frequently. The wobbly grate was another inconvenience. The role of women, however, does not have to be restricted to giving inputs regarding their needs and preferences. In Dhanawas, women who were trained as chulha mistris constructed almost all the chulhas that were disseminated. These concerns are yet to find place in the national programme. Under the NPIC, the MNES has recently (during 1997/98) instructed its various state nodal departments, implementing agencies, NGOs, technical back-up units, etc., to conduct training programmes for women that would include demonstration on operation and maintenance and information on technology, bank loans, and approved manufacturers. Though a significant step in the right direction, the need for such an initiative was required long back. Micro-level studies done in the past, including the Dhanawas experience, repeatedly emphasized the need for information dissemination and capacity building of the users. However, there is no forum at the national level where these suggestions/recommendations can be put forth.

Objective of household energy programmes

The most important learning, which has been borne out by other experiences also, is that improved fuel efficiency cannot be the sole objective of a household energy programme. It must compete with and complement other features like smoke reduction capability, convenience of use, safety features, and attractiveness. In fact, these factors may even take precedence over the fuel-saving benefit. There is no mechanism in the programme to match individual needs with overall programme goals. It was seen time and again in Dhanawas (where fuelwood shortage was not felt by a majority of the farmers) that the main reason for adopting improved chulhas was the smoke removal ability and not the fuel-saving potential of the stove. Again, the main reason for people discarding the use of Nada chulha was its poor durability. While the model was superior to the traditional cookstove in terms of fuel saving, it suffered limitations in other respects that were important to the people. Similarly, TARA metal stove was found unsuitable for making rotis, the staple diet of the people.

Programme integration

The programmes in Dhanawas lacked the holistic concept of programme planning and implementation. The biogas programme was started as a field-testing exercise with the entire focus on technology development and demonstration. With time, as the demand for biogas grew, there was an attempt to assimilate the activities. There was, however, no attempt to integrate the biogas and improved chulhas programmes. These were never considered as a mix of technological options available to the household to choose from. This integration of household energy programmes is also missing at the national level. The NPIC and the NPBD are implemented independent of each other in physical terms, though the objectives of both are similar. At the larger level, there is no integration of energy programmes with other development programmes such as housing, education, health, and sanitation. The need for such integration was also felt after working for a long period in a village like Dhanawas where household energy was not a priority of the people and still remains so. Where priorities of the people lie outside the realm of energy, it becomes even more important to integrate energy interventions with other developmental programmes.

Programme integration is, however, difficult if there are no policies driving such integration at the national level. Where the several ministries and government departments have their own programmes, targets, and strategies of work with no interaction with each other, integration at the grass-roots level also becomes difficult.

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Chapter 6

Biomass gasifier

Rural energy matters: the Dhanawas experience 81-87

Background

Biomass utilization through gasification was recognized as an important renewable source of energy for the country in the mid-1970s. The groups that were studying biomass utilization in the late 1970s and early 1980s were the Indian Institute of Technology, New Delhi; M/s Jyoti Ltd, Baroda; and SPRERI (Sardar Patel Renewable Energy Research Institute), V V Nagar. The NARI (Nimbkar Agricultural Research Institute), Phaltan; PAU (Punjab Agricultural University), Ludhiana; and the IIS (Indian Institute of Science), Bangalore were also working on biomass gasification. Interest in small-size gasifiers coupled to diesel pumps (3–7 hp) started gaining momentum in the 1980s, after the DNES launched a nationwide programme for demonstration of gasifiers – the Biomass Production, Conversion and Utilisation Programme. Wood-based gasifiers were largely promoted so as to couple the gasifier programme with the social forestry or agroforestry programmes. The gasifier programme in India initially concentrated on developing gasifier-based irrigation pumps with 5 hp capacity, with the ultimate objective of replacing the huge number of diesel pumps operating in the country. But, the confidence generated expanded the domain of end uses to be covered under the programme to include power generation and thermal applications.

It was in this setting that TERI entered the field of developing the biomass gasification technology in 1986. Though several gasifiers were operating at that time, they were highly fuel specific. Due to the physico-chemical, spatial, and seasonal variation of biomass residues in India, there was a need to develop a multi-residue-based gasifier system. The technology development and demonstration in Dhanawas was an important phase in the evolution of a small gasifier-based power plant for rural and decentralized applications.

Development of the gasifier

After the initial experiments at the Institute's office premises in New Delhi, it was decided to develop and field test a 7-kVA prototype in Dhanawas. A gasifier system (6 kW) with a briquetting machine (5 kW) was installed in Dhanawas in May 1990 under a project sponsored by the MNES. The two specific objectives of this initiative were to (1) provide electricity to the village temple and (2) produce briquettes.

Preparatory work

As the first step, a village-level survey was conducted to assess the type and quantity of agro-residues available. It also aimed to estimate the excess waste available, which could be used for the gasifier. The problems encountered in data collection were as follows.

- There was no standard measure for quantifying crop residues. Data had to be obtained in terms of tractor loads, camel carts, etc., conversion factors for which were not available. Though some farmers gave a rough idea of conversion factors, there was no agreement between them.
- The quantities quoted by them did not include the residue that was left in the fields.
- All the residues were not transported from fields in bulk. For example, mustard stalk was stocked in the fields and brought home in parts. This complicated the estimation procedure.

The survey showed that the most promising fuel for the gasifier in Dhanawas would be mustard stalk, followed by gwar and bajra. Almost the entire amount of stalks required for operating the system could be obtained from a single household.

It was clear that the gasifier could not be used for water lifting. This was because most households had private pumps. Further, if the system were privately owned and operated for irrigating fields, it could lead to conflicts within the village. Also, Dhanawas did not have community wells for drinking water as most of the families had their own sources of water or used tap water. Thus it was most desirable to use the gasifier to generate electricity and supply it for street lighting, especially since there was not a single street light in the village. The villagers also considered supplying electricity to the village temple as an acceptable option. The temple authorities were willing to provide land for installing the system.

Since capacity of the system was too small to couple it with the grid, the gasifier was used as a stand-alone unit delivering electricity on demand, providing substantial end use/user flexibility. The electricity demand was confined to the needs of the temple. As the system capacity was higher than that needed for the temple, it was decided to produce higher quantities of briquettes for use as possible replacements to dung cakes in the hara.

The idea of installing a gasifier was introduced to the VEDC first and its permission to work was obtained. The VEDC and the panchayat suggested the site of the temple for this purpose. Though their main interest was in using gasifier electricity for running agricultural pumpsets, they did not object to the use for street lighting, as suggested by TERI.

About the gasifier

The gasifier was a downdraft throatless gasifier with a low specific gasification rate (Figure 1). The emphasis in technology development was on fuel and end-use flexibility. It was an integrated system capable of utilizing several biomass residues as fuel. It was a fuel-processing and power-generating system. The system could be assembled on a single trolley, making the complete unit an independent source of energy suitable for rural applications in remote areas. The salient features of the gasifier system installed in the village are given below.

1. It was the first multi-fuel gasifier to be installed. Other commercial gasifiers were all wood-based.
2. It was the first of its kind to be assembled on a trolley and installed in the village for demonstration and performance study.
3. The gasifier system was integrated with a fuel-processing subsystem.
4. It had a downdraft throatless design, which helps in obtaining clean producer gas and allows smooth fuel movement.

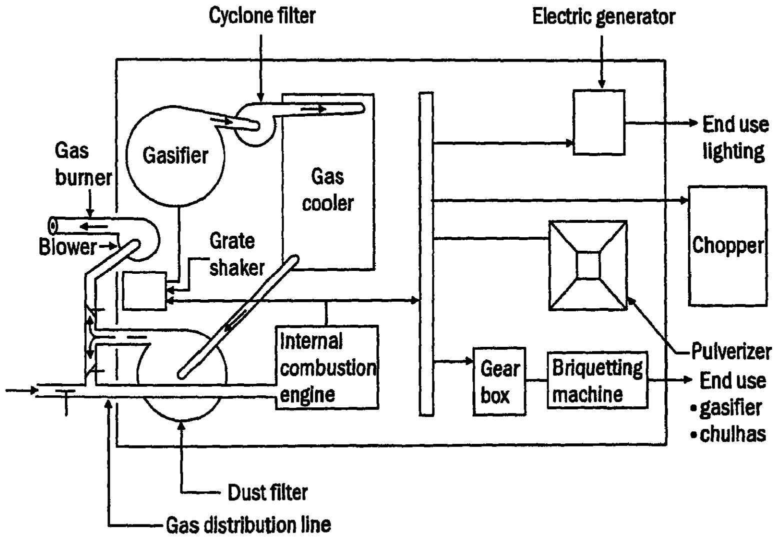

Figure 1 Representation of the briquetting gasification system

5 It had a low specific gasification rate with smooth fuel movement due to larger diameter.
6 It had a continuous ash removal system so as to handle fuels with high ash content.
7 There was low pressure drop across the gasifier system.
8 Its higher reactor temperature ensured better quality of gas with less tar content.
9 Its fuel-bed agitator ensured smooth fuel movement in continuous operation by avoiding bridging in fuel bed.
10 It had the ability to use different biomass residues.
11 It was a novel multi-stage gas cleaning and cooling system.
12 It was simple in construction, requiring negligible maintenance.

At 1989 prices, the total cost of the system was about Rs 70 000. Though the initial objective of the project was to develop a non-wood biomass gasifier system for pumping water for irrigation, the system which finally evolved was a multi-purpose one that could be used for any motive power application.

Performance of the system

The gasifier was run for about four years (from April 1990 to February 1996). It was used for electrifying the temple complex, to run a pump in the temple, and to produce biomass briquettes. Fuel processing was done during the day and the briquettes were stored in bins for subsequent use. The main use of the gasifier was during festivals. During daytime, it was used for running a fan.

Visitors at the gasifier unit

During these four years, the system was closely monitored. The system performance showed that, in dual-fuel mode, it was possible to replace almost 70%–80% diesel with producer gas (Raman, Dhingra, and Kishore 1990).

Detailed observations were made about operational aspects. The operational problems were that the engine had to be overhauled once in two years and that it required frequent cleaning of the inlet of cyclone and others as the dust content in the gas was high. It was also felt that the scale of the present system was too small and that a commercial ram and piston briquetting machine might give better quality briquettes than the screw extruder. From considerations of the motor capacity needed for the smallest (100 kg/h) commercially available briquetting machine, the capacity of the power plant was calculated to be 40 kW (Raman, Dhingra, and Kishore 1990).

Briquette production

Using the gasifier, briquettes were also made for use as an alternative cooking fuel. After a year of operation, a simple char-making system was also installed at the site and the char obtained from mustard stalks was used to make char briquettes in the same extruder. Char and green briquettes were distributed in some households, roadside restaurants, and tea stalls. The tea stalls and roadside restaurants did not find them very useful mainly because most of them were adjacent to the railway track and were able to procure coal easily. An angithi, the device used for space heating / cooking, runs for 4–5 hours if filled with coal. Briquettes, on the other hand, burn for a shorter duration, requiring the angithi to be charged more frequently. Despite these drawbacks, in 1992/93, a few families in Dhanawas used these briquettes in angithis for room heating. Some of the families also used them as cooking fuel and as a replacement for dung cakes in hara. The people appreciated briquettes as they emitted less smoke and lasted longer than dung cakes. These were sold at Re 1/kg and the demand for briquetted fuel increased rapidly. However, the system size was not enough to meet this demand and the money needed for increasing the system size was not available. Further, the life of the gasifier was 4–5 years, which was almost over by this time. As a result, the price of briquettes was increased to Rs 1.50/kg. The system of selling briquettes was soon replaced by a system where the people could get their crop residue briquetted for a price of Re 0.5/kg. During the visit of the then Honourable Secretary of Energy, USA, Ms Hazel O'Leary, in February 1995, the gasifier was also used for lighting the street from the temple to the village school.

Operation and maintenance of the unit

The unit was operated and maintained solely by TERI staff throughout its period of functioning in the village. Mustard stalk was bought from the villagers for briquetting and as such no formal arrangement was designed wherein the people were involved in material procurement or operating and maintaining the unit.

Upscaling the gasifier: the post-Dhanawas phase

As a follow-up to the work done in Dhanawas, which entailed increasing the capacity of the gasifier, a proposal was submitted to the MNES for the development of a 50-kW power plant based on briquetting–gasification. In 1992, the MNES approved the proposal. In February 1996, the gasifier in Dhanawas was shifted to the TERI campus in Gual Pahari, Haryana. Since then, several design improvements have been carried out and high diesel replacement rates (of the order of 70%) have been obtained over a load range of 0–50 kW using wood and sawdust briquettes. The waste material from the system (char, ash, and washed away tar) can be charred without adding a binder to make char briquettes that can be used as fuel. Presently, the system is ready for installation at the TERI hostel in Gual Pahari.

Conclusion

The experience in Dhanawas was carried forward and TERI was able to develop an integrated briquetting–gasification based power generation system. This system has the potential for decentralized power generation in rural areas by utilizing a variety of agro-residues. The system can be used to meet the energy needs of villages that have agro-residues in abundance and use them as fuel. This would cover the northern India states of Haryana, Bihar, Madhya Pradesh, Punjab, Rajasthan, and Uttar Pradesh. Besides providing electricity, the technology can be used to retrofit diesel engines used for agricultural purposes. In addition, biomass briquettes, which serve as a good alternative for dung cakes and coal that are traditionally used for cooking, water heating, and space heating, can be produced.

The gasifier unit set up in Dhanawas for demonstration showed good results. The reasons for withdrawing the gasifier unit from the village were organizational and had nothing to do with the viability of the technology. The system was operated successfully for a five-year period, of which almost for three years the Institute fully supported the activity at its own cost. As a follow-up, the system was upgraded and now it is to be installed at TERI's hostel campus in Gual Pahari. However, even now, much research needs to be done to make the technology mature enough for wider electricity-based applications in the rural areas. The unit to be set up at the TERI hostel campus will be monitored continuously for further improvements.

From the programme planning and implementation perspective, however, not much could be gained from the experience. Taking the technology to the field, and that too in a village setting, could have been used to gain valuable lessons in the management of the intervention by organizing the village community, building local capacities, and setting up requisite institutional mechanisms for programme management. The lessons learnt from the experience were mainly in the area of design improvements, which have been successfully used for upgrading the system.

At the policy level, the MNES continues to support the installation of gasifiers as stand-alone systems for power generation for a variety of applications. This is being done with the confidence that the technology is mature enough and can be disseminated on a large scale. The experience in Dhanawas and its follow-up at TERI's Gual Pahari campus shows otherwise. There is, however, no forum where such research findings can be brought to the attention of the policy makers and planners so as to bring about effective changes in programme formulation.

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Chapter 7

Solar and other technologies

Rural energy matters: the Dhanawas experience 89-101

Solar technologies

A number of solar technologies were demonstrated for their technical feasibility and social suitability. The end uses targeted were water heating, cooking, lighting, and water lifting. These end uses were identified based on energy surveys and the expressed needs of the people. The pre-surveys (TERI 1984) carried out in Dhanawas showed that a considerable amount of energy was being expended on water heating. The study revealed that water heating accounted for 18% of the household energy consumption. In summers, 40% of the households used crop residues and 7% of the households used commercial fuels for water heating. In winters, 75% of the households used dung cakes for water heating.

In response to this need and the fact that the region had abundant insolation, TERI decided to experiment with solar technologies and modify them to suit the requirements of the village. The solar technologies introduced in Dhanawas were SWH (solar water heater) and the SSP (solar shallow pond). At this stage, the objective was to demonstrate the technologies to determine their applicability and reasons for acceptance/ rejection by the people. As the R&D objective was to test their suitability to village conditions, provision for regular and systematic monitoring of the technologies was in-built in the demonstration activities. Monitoring typically included

- measuring field performance: time-series performance and durability of the device
- assessing impact on energy use pattern
- integrating the technologies in the day-to-day living of the people.

The other solar technologies introduced included solar cookers, solar domestic lighting kits, SPV (solar photovoltaic) lanterns and street lights, and SPV pump for water lifting. The process of demonstration/dissemination of these technologies has been described in detail in the following sections.

Solar water heater

The 1984 survey and the 1987 AIUN survey indicated that before attempting large-scale dissemination of SWHs, a few units should be demonstrated to determine device compatibility with respect to the hot water requirements of the households. A pre-installation survey of the potential households was carried out and baseline data were collected on requirements for hot water, usage patterns, devices, pots, etc. The following criteria were used to select households for the demonstration of devices.

- The household must be willing to use the device regularly.
- The household must have a person who is willing to operate and maintain the system regularly.
- Families with school-going children would be given preference, as they require hot water in the mornings.
- As the SWH had to be installed only in a place where there was no shade, a house with an open terrace was preferred.
- The house must have a permanent arrangement to go to the terrace like a staircase.
- There should be a water source nearby.

Two units of a water heater designed by TERI were given on a demonstration basis. These had tube lights that functioned as collectors of sunlight throughout the day. Subsequently, five units of another design were also installed. These units were provided with toughened glass as the collector of sunlight. The SWHs were tried out for about a year. The second design performed satisfactorily; however, its maintenance requirement was quite high. TERI took care of this in the demonstration phase. The first design did not give a satisfactory performance. The cost of these SWHs was also high (about Rs 1000). At the end of the demonstration period, it was concluded that the devices were not suitable for large-scale dissemination in the village. The constraints identified were as follows.

- The cost was so high that villagers would not have bought them even at a reasonable subsidy.
- The water, even if slightly saline, caused rusting inside the uni and the water in most parts of the village was a little brackish.
- The SWH was able to supply hot water only by mid-morning (10 a.m. to 11 a.m.) while the main requirement was i early mornings.

The activity was thus discontinued in the village.

Solar shallow pond

After the demonstration of SWHs in the village, experiments were carried out with another device for heating water, the SSP.[1] The primary advantage an SSP offers over an SWH is that it can supply hot water at any time, day or night. Unfortunately, this technology also could not be taken beyond the experimentation stage because the saline water caused the pipes to rust and sand accumulated in the pipes. The villagers also found the device difficult to use.

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[1] The SSP is a horizontally shaped system that requires electrical pumping and can be installed in any size on an elevated place. A collector area of 1 cubic metre can produce about 30 litres of hot water per day at 50 °C.

Solar cookers

Box-type solar cookers were demonstrated on an experiment basis in six households to assess their viability in the rural setting. The recipients were selected through the lottery system. Though the cookers were used enthusiastically for a few months, people found them unsuitable for their diet and cooking habits. Later, only two cookers were used and that too not very often. The cookers were considered unsuitable due to the following reasons.

- Cooking time in the village did not match with periods of maximum solar insolation. Most people cooked meals in early mornings and in the evenings, while the insolation was highest during the day.
- Rotis could not be made in the box-type cookers.

These cookers were taken back after a year and the activity was discontinued.

Solar photovoltaic water pump

Scarcity of potable water has always been a problem in the western part of Dhanawas. While, the groundwater is potable in the eastern part of the village, it is alkaline (pH of around 7.6) in the western part. About 65% households, constituting one of the major clusters in the village, faced acute shortages of potable water. In this part of the village (i.e. the western part), the water requirement was being met by piped water supply provided by the PHD (Public Health Department) under a scheme started in 1980. The water supplied through the system was, however, highly inadequate and erratic. Especially during the summer months, when the demand for water is at its peak, several days would go by without any water reaching the village. The main sources of drinking water in the village were open wells. The women spent at least 2 hours everyday fetching water. Among the various communities living in the village, the harijan families were the worst affected. There were very few hand pumps in the village and none of the harijan families owned one.

The scarcity of potable water was discussed at several village-level meetings. The different options considered included making the existing wells that ran dry in summers deeper and digging a borewell in an existing well and installing a hand pump. The second option was ruled out as it would require regular maintenance. Further, it would not meet the needs of the entire village. There was also a debate on whether the hand pump should be installed in the harijan well or a common well. No decision could be taken on this issue, as the expected expenditure (almost Rs 10 000) could not be met from the panchayat funds.

In 1995, the then Honourable Secretary of Energy, USA, Ms Hazel R O'Leary, visited Dhanawas. At the time of her visit, the Embassy of the United States of America expressed a desire to gift a community asset to the village. The embassy approached TERI and requested it to suggest a renewable energy technology device that the villagers would appreciate. When the matter was discussed at a village meeting, the community raised the drinking water issue and asked if something could be done about it. The decision to install an SPV water pump in Dhanawas was a response to this need of the village.

Site selection and system sizing

A number of village-level meetings were held to resolve the issue of where to install the pump. After several rounds of discussions involving the VEDC, the villagers, and TERI, it was decided that the SPV pump should be installed at the harijan chaupal (a community area), on the eastern side of the village. The site selected already had an open well into which the submersible pump was installed. The most important factor that was considered while selecting the installation site was accessibility to the maximum number, including the worst affected. Other factors considered were (1) land ownership, (2) space, and (3) insolation. To rule out the possibility of any dispute, land ownership had to be community-based. Regarding space requirements, the site had to be large enough to put up a storage tank and install solar panels and a junction box. The site had to have adequate insolation.

It was also important that the families living around the site should feel a sense of ownership vis-à-vis the pump, even though they may not be the primary beneficiaries. This would provide some measure of security.

In order to decide the size and capacity of the solar pump, a rapid survey was conducted in about 50 households to estimate the average domestic water consumption. The data collected indicated that the consumption per capita was in the range of 40 litres per day, which aggregated to a total demand of 42 000 litres per day. Accordingly, the capacity of the pump was decided at 50 000 litres per day. On the basis of the total consumption at the village level, it was decided to provide for a storage capacity of about 20 000 litres.

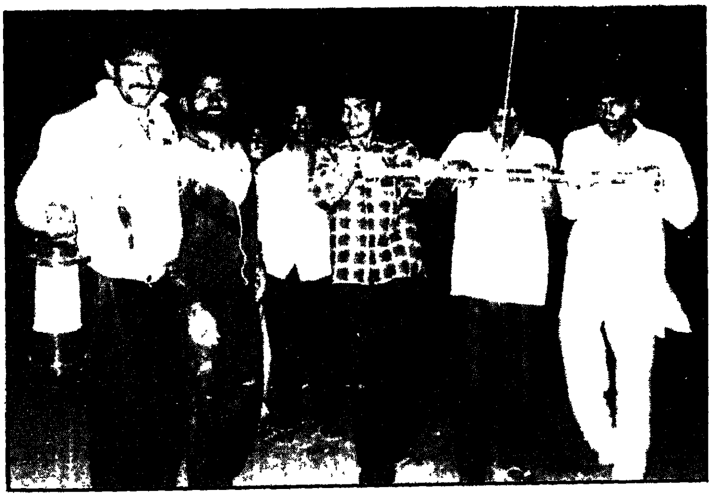
Installation

The SPV pump was installed in July 1995. The Central Electronics Limited, Sahibabad, carried out the installation work with support from the villagers and TERI. The installation work, which carried on late into the night, was like a village function, in which a large number of the village youth and children participated enthusiastically. In fact, as one of the village elders described it, the occasion resembled a village wedding. The existing well was cleaned and made deeper, and a submersible pump of 1.5 hp capacity was installed. Initially, a storage tank of 5000 litre capacity was installed on a raised platform.

Seeing the growing usage of the pump, some experiments were conducted by TERI in February 1996 to see whether the existing capacity would suffice for the coming summer months. The data collected indicated that the output in summer would be 40 500 litres per day (assuming 9 hours of sunshine). In winters, it was expected to reduce to about 25 000 litres per day. During monsoons it was expected to be 32 000 litres per day (again on a sunny day). However, this would not cause a major problem because the consumption of water would also decrease substantially during these months.

Feedback received from the villagers indicated they were satisfied with the performance of the system. According to them, the main advantage of the SPV system compared to piped water supply is the flexibility it offers in terms of time of usage. Unlike the PHD supply, which is time-bound, the water supply from the SPV system is uninterrupted and continuous (because of storage facility).

Village youth drilling a borewell for installation of the pump



Need for a decentralized water distribution system

In 1999, around 70 families in the village were using the pump for fulfilling their needs for drinking and cooking. Thirty families also used it for feeding and bathing their cattle. As expected, the families living at a distance found it less useful and the women from these families (almost 100) came to the pump site only to wash clothes. These families started requesting that the water be piped to a few other sites from where other households could conveniently fetch water. The need for increasing the storage capacity was also heightened by the fact that the water being pumped was far in excess of the storage capacity of 5000 litres and was flooding the low-lying area adjacent to the pump site. This was unhygienic and posed the danger of becoming a breeding ground for mosquitoes.

The matter was discussed at length at several village meetings as well as within the VEDC. While everyone agreed that this would increase the utility of the pump manifold, funds were not forthcoming. The panchayat did not have enough funds to pay for the decentralized piping and distribution system, which was expected to be in the range of Rs 200 000. In the absence of any other source of funds, it was decided that the households that would avail of this facility would make contributions towards the initial investment.

The work on this system was commenced in 1997/98. By 1999, a tank and three taps were fixed for a cluster of 12 households that lived close to each other. This was the first set of families that took the initiative and collected contributions

The SPV water pump in Dhanawas

of Rs 8000 per household. The money collected was used in erecting the tank and civil works. The cluster of user households formulated a set of rules and regulations for the use of this water. It was decided that the water would be used strictly for drinking and other domestic purposes. No washing or bathing would be allowed at the tank site. Cattle were not to be brought to the tank site. As the system is decentralized and modular in nature, it was decided that the distribution pipes would be extended and additional tanks constructed as and when other clusters of households mobilized money.

TERI's role in the management of the water distribution system decreased gradually. While the initial discussions on setting up such a distribution system were facilitated by TERI, the responsibilities of collecting contributions, drawing up rules and regulations, regular maintenance and upkeep of the system, etc., lie completely with the villagers. The responsibilities of the panchayat are as follows.

- Maintaining the pump and the distribution pipeline
- Resolving conflicts and problems arising in the distribution of water
- Carrying out repair works
- Checking the quality of water periodically

A local person was trained for the operation and servicing of the pipeline, taps, etc. Information regarding whom to contact for repair of the pump was provided to the panchayat. An annual maintenance contract was signed with a local technician, whose expertise was assessed by TERI. The technician would be paid for his services by contributions collected from user households. TERI was to provide technical expertise (monitoring) till 1999.

Solar photovoltaic lanterns

In 1995, the then Honourable Secretary of Energy, USA, Ms Hazel O'Leary, gifted 62 solar lanterns to the villagers. The initial feeling among the villagers was one of jubilation and the solar lanterns were appreciated greatly by the users. However, as they were clearly inadequate in numbers for the whole village (in 1995 there were 190 households in Dhanawas), major problems were faced in their distribution. In fact, the free distribution of lanterns was an event that created a host of problems for the TERI project team and also necessitated a complete change in the Institute's strategy for village-level work.

Distribution

Once the lanterns reached the village, it was evident that no matter what method was adopted for selecting the households,

The then Honourable Secretary of Energy, USA, Ms Hazel O'Leary, presenting a solar lantern to a village woman. Mr Krishna Kumar, the then Minister of State for Non-Conventional Energy Sources is also present

the distribution would leave a large number of households disgruntled. Therefore, it was decided that the VEDC should take the responsibility of coming up with a rational criterion for selection of households, which would be acceptable to all. Also, the VEDC was to carry out the distribution of solar lanterns. For TERI, it was important not to get involved in the distribution process for two reasons. Firstly, the lanterns were clearly a direct gift to the village community and, to this extent, TERI was a party external to the event. Secondly, it was important for TERI to maintain objectivity in the issue and let the villagers handle the matter. This was because certain influential persons in the village were beginning to feel threatened by TERI's popularity. Some elders felt that while there was no escaping the fact that some people would react strongly if they did not get a solar lantern, a decision made by TERI would be far more acceptable to them than the decision coming from the sarpanch. However, a conscious decision was taken at the Institute level that TERI would, under no circumstances, get involved in this matter.

The possibility of pricing the lanterns was explored for some time, but was finally dropped as it had been announced in no uncertain terms that they were a gift to the village community. As expected, the village politics played an important role in deciding who should get a lantern and who should be left out. It had been decided by the VEDC that each of the VEDC members should get a lantern each. It was felt that the distribution should be such that families from all the clans and communities get at least some lanterns. However, after a lot of altercations, the sarpanch managed to use his clout and apart from the VEDC members, all the families who got lanterns were either his staunch supporters or of some influence in the village.

Usage

Before the lanterns were put to use, the people were guided and trained about their upkeep and maintenance. Though there was some scepticism in the minds of the people initially regarding their utility, all the families that used the solar lanterns found them very useful. The PV lanterns distributed had two small 6 W lamp tubes. It required low maintenance and had rechargeable lead–acid batteries. It could be used in all weathers, both indoors and outdoors. It could provide light for 5 hours, when fully charged.

Children studying in the light of a solar lantern

The users found the solar lanterns extremely useful because it extended their hours of work. The children could study after dark. Attending to animals at night also became easier. Women found cooking much easier in the light of the solar lantern. Some users also reported savings in kerosene. The lanterns proved very useful when there was no electricity supply for days together. The lanterns were found very handy to use and could be handled by all members of the household.

Maintenance and back-up support

Over the years, villagers faced some problems in maintaining the solar lanterns. Most of these problems were technical in nature. A physical check-up of all the solar lanterns was carried out in 1998. The reasons for non-functionality were identified as tube and battery failure. It was, however, not possible to replace the batteries and tubes due to high cost of replacement. The batteries are also not available in the nearby town of Gurgaon and are available only in Delhi. The users were also quite apprehensive about the quality of batteries available locally. To overcome some of these problems, two local persons were trained in the repair and maintenance of the systems. The users were informed from where they could buy quality batteries and tubes.

Domestic solar lighting kits and solar street lights

Besides solar lanterns, the village also received four solar home lighting kits and two solar street lights from the US Embassy. The solar home lighting kits provided three light points (9 W fluorescent lamp), which could be fixed at different points in the house. Solar panels were mounted on the roof for adequate insolation. The site for installation of kits was decided after detailed discussions with the VEDC. These were the panchayat office, community centre (harijan chaupal), TERI office-cum-residence, and the village temple. An assessment of the benefits as perceived by the users included savings in kerosene, availability of three points for lighting, convenience in usage, and reliable power supply.

Two solar street lights were also installed, one at a central point in the village and the other at the village community centre. In the case of solar street lights, the solar panels and

Installation of solar street light - the community lending a helping hand

light (24 W fluorescent tube) were mounted on top of a pole. The battery box was fitted at the base of the pole. According to the villagers, the street lights facilitate easy movement at night and they can carry out social activities after dark.

In the case of these two devices, the only problem that was faced was one of location. Certain groups of villagers tried to usurp the benefits of these devices by demanding that they be installed near their homes. This issue was discussed during meetings with the VEDC. One of the solar lights was installed near the solar pump site, which has proved to be of great use as the people could now use the pump at night. It also provided a measure of safety for the expensive solar panels. The other light was installed at the main crossing or chauraha of the village, where it continues to benefit a large number of people.

Other experiments

As irrigation is an important end use of energy in the agricultural sector, a study was taken up to examine the scope of improving the performance of agricultural pumpsets in the village. A survey was conducted to procure and compile detailed information on the existing pumpsets in the village (capacity, nature of power transmission, and age). Underground water was the only source of irrigation in the village. Hence, both electric and diesel pumpsets were used for this purpose. Of all, 61 farmers (out of 96 farmers) owned 90 pumpsets – 63 electric and 27 diesel. In addition, there were three Persian wheels one of which was not in use. A majority of the large farmers owned both electric and diesel pumpsets, the latter being kept as stand-by. In the marginal farmers' category, only 30% households owned pumpsets. Those that did not own a pumpset were purchasing water at the rate of Rs 50 per acre per irrigation. Electric pumpsets were preferred by a large number of villagers as they were easy to operate, required less capital, and had a low running cost compared to the diesel pumpsets. A majority of the electric pumpsets (89%) were of the monobloc type and the rest were the belt and pulley type. The electric pumpsets were of 3 and 5 hp rating, whereas the diesel pumpsets ranged from 5 hp to 8 hp. Most electric pumpsets were of 3 hp.

A study of the available methods to improve pumpset efficiency was carried out. The activity, however, could not be pursued primarily due to cost considerations. As far as the electric pumpsets were concerned, the farmers had no incentive to invest in energy conservation measures because of the highly subsidized tariffs for electricity. In 1987, the average electricity expense incurred on a 3 hp pumpset per year was

Rs 503 per hp and that on 5 hp pumpsets was Rs 460 per hp (Kohli et al. 1992). The average expense was in the range of Rs 2.15 per acre per hp.

A nocturnal water cooler was also installed in a place of common use for demonstration purposes. This was discarded as nobody took the responsibility for taking care of it. It was not found to be effective either. The users felt its performance was similar to that of a mud pot.

Ramification of 'free' distribution of devices

Increased exposure of the villagers to visitors led to several attitudinal changes in the people. The change that affected the functioning of the field staff most adversely was the feeling among the sarpanch and his coterie that Dhanawas had become indispensable for TERI. This feeling was a direct consequence of their finding out that the solar devices had been financed by external agencies. The sarpanch who felt threatened tried to leverage decisions to his personal gain at several occasions.

Another change that came about as a result of these visits is that the villagers began to feel that TERI as an organization was very influential. The villagers had always wanted more activities for the general development of the village such as construction of road, building of a boundary wall for the village school, installation of hand pumps, etc. When the construction of a road was co-financed by TERI and the block office during the visit of the then Honourable Secretary of Energy, USA, Ms Hazel O'Leary, in February 1995, there was a feeling that it should be possible for TERI to take up other developmental activities as well. Some of the villagers also expected increased financial support from the Institute and jobs for unemployed villagers including employment opportunities in the Institute itself. Hence, despite repeated efforts of the Institute to moderate the expectations of the villagers, the people were always looking for increase in economic opportunities and overall development of the village.

Conclusion

The solar technologies, though technically feasible, never took off beyond the stage of experimentation. The main reason was that these did not match with the lifestyles of the people. This only goes to show that it is not only important to ensure that the technology addresses a felt-need of the people, but that the technology fits into the lifestyles of the people which is determined by sociocultural factors that are location specific.

It is also essential to study the traditional methods that people have adopted for meeting a particular need. These may be preferred particularly if they are more cost-effective than the new technology. Nocturnal water coolers were not well accepted in Dhanawas primarily because earthen pots were sufficiently meeting the requirements of the households. The experience with the installation of the SPV pump shows that where people have no monetary stake in the intervention, sustaining the intervention becomes more a responsibility of the agency than that of the people benefiting from the intervention. Likewise, the distribution of solar lanterns at no cost would have made sense only if each household was to receive one and the benefits were shared equally by all members of the community.

The solar cookers, SWHs, and SSP did not reach beyond the demonstration stage. Therefore, to conclude anything at the level of programme planning, implementation, and policy making is rather difficult. It cannot be overemphasized that the need for effective planning wherein the role of people and the agency is clearly defined and the benefits are equally distributed is extremely important to avoid misconceptions and disputes.

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Chapter 8

Reclaiming degraded land through energy plantation

Rural energy matters: the Dhanawas experience 103-115

The wasteland development programme was one of TERI's key programmes in Dhanawas. This was an important experiment both from the research point of view and a management perspective. From the research angle, the challenge lay in reclaiming a completely degraded patch of land and improving the quality to an extent that it could be used for cultivating agricultural crops. On the management side, when a worthless piece of land of no value was slowly converted to a prime agricultural plot, monetary interests came into play and this gave rise to a large number of social and political issues in the village. For TERI then, the plantation, which started as a purely technical experiment, assumed other dimensions of managing these social realities. To this extent, the plantation in Dhanawas was a good learning experience in managing programmes with the local people.

Background

The Dhanawas panchayat had about 105 acres of land, which lay scattered as small plots in and around the village. This land was largely barren because of salinity and water-logging. In 1984, the Institute entered into a lease arrangement with the Dhanawas panchayat under which 20 acres of panchayat land was given to TERI for five years for wasteland reclamation through forestry activities. The leased site was a low-lying area used primarily for grazing. As this particular patch of land was in a depression, it suffered from water-logging during the rainy season, with water flowing into the site from adjoining farms. Further, the very dry and hot summers parched the site, resulting in the formation of deep cracks. The alternating drought and water-logging conditions were not conducive for the growth of any vegetation at the site. In addition, the continued use of the site for grazing further compacted the soil, making it unsuitable for any kind of vegetation growth. All these factors resulted in the leaching of underlying salts to the upper layers. The site thus became highly sodic with a pH value of nine plus, and was locally known as 'kallar' or 'usar' land.

The work on raising the plantation in the 20 acres of panchayat land was started in July 1984, with the twin objectives of supplying fuelwood to the villagers and reclaiming the wasteland.

Initial experiments

In the initial stages, experiments were conducted on 11.5 acres saline community land. The objectives of these experiments were to

- identify suitable fast-growing species capable of withstanding a high level of alkalinity, which could also be used as fuelwood
- examine the economic feasibility of afforestation in these types of soils.

The first steps in this experiment involved dividing the site into equal sized plots, collecting soil samples, and testing the soils. The tests showed that the soil was highly alkaline in nature (pH ranging from 9.7 to 10.4). The water available in the area was also tested. It was found to be slightly brackish but safe for irrigation. Initially, seven different species were selected (Table 1).

Table 1 Species selected and the recommended pH

Species	*Local name*	*Recommended pH*
Prosopis juliflora	Vilayati babul	9.5-10.5
Acacia nilotica	Kikar	9.5-10.5
Eucalyptus hybrid	Eucalyptus	9.0-9.5
Dalbergia sissoo	Shisham	9.0-9.5
Leucaena leucocephala	Subabul	8.5-9.0
Azadirachta indica	Neem	8.5-9.0
Albizia lebbek	Siris	8.5-9.0

All species except *Prosopis juliflora* and *Acacia nilotica* needed partial soil amelioration. For this, the soil was treated with gypsum and cow dung. In addition, BHC (benzene hexachloride) was also applied.

Of the 9018 saplings planted, very few survived during the first year due to high salinity and water-logging. The average mortality of seedlings after three months of planting (varied for species to species) was nearly 6.4% (Bose and Bandoyopadhyay 1986). The species that did best were eucalyptus, shisham, and subabul. All the dead plants were replaced in October 1984. After six months of planting, the mortality rate was the highest for kikar (14.3%). The initial capital requirement per hectare for afforestation in alkaline soils was in the range of Rs 15 000 (at 1984 prices). The anticipated recurring (maintenance) expenditure was expected to decrease over the years – from Rs 2500/ha in year 1, to Rs 1580 in year 2, Rs 1757 in year 3, Rs 750 in year 4, and Rs 500 in year 5.

Based on certain assumptions, a detailed cost-benefit analysis was also carried out for the plantation. The results of the analysis suggested that an investment of Re 1 in the plantation would provide benefits of Rs 1.24, and the net present value of the benefits and costs would be Rs 22 509/ha for a 10-year period.

Soil treatment and nursery raising

Treating the soil and gradually increasing the plantation were the two main activities from 1985 to 1987. In 1986, a new plantation plan was developed and appropriate species were selected to suit the soil conditions at the site. Around 10 000 saplings were planted. In the first batch, species such as *Albizia lebbek, Dalbergia sissoo, Leucaena leucocephala, Acacia nilotica,* and eucalyptus hybrid were planted. These plants also did not do very well. The region was hit by a drought in the same year and the plantation suffered severely from it. The problem of water shortage was further aggravated by the absence of an artificial source of irrigation. In 1987, a diesel pump of 8–10 hp was installed at the plantation site. In the same year, TERI established a nursery on 1 acre land within the plantation area. The soil was treated with dilute sulphuric acid, which decreased salinity and made the soil more conducive to young plants. The planting of *Dalbergia sissoo* trees checked future accumulation of salt.

Labour for planting activities was hired from the village itself. These labourers were mainly from the economically backward households and the majority were harijans. Many

A local woman employed for nursery raising women from the village were also employed for planting and for nursery raising.

Plantation fires

In 1988, a fire broke-out in the plantation area accidentally. Between 1989 and 1994, two more major fires occurred. These were again accidental fires. On both occasions, the fire spread rapidly because of the tall grasses growing on the plantation (the land was not open to grazing). In the first fire, nearly half the plants were destroyed. In the next fire, which originated from the adjoining government plantation, nearly 18 acres was destroyed. These fires completely destroyed the small plants. The bigger trees and plants, though damaged, recovered eventually and survived. However, the growth of some of these became stunted. The cause of these fires could never be ascertained. The most probable explanation for the two fires was that after the government plantation was cut, people used to burn grasses so that the wood (stumps) could be easily cut.

The need for protection measures against fires was recognized. As a remedial action, new plants were planted between the rows that had been destroyed in the fire. Fire lines were also made. These activities dominated the following years of the plantation.

The plantation and the villagers

Over the years, a variety of tree species were tried for plantation. By 1999, the plantation area had around 5000 trees of the following tree species: shisham, kikar, neem, vilayati babul, siris, and eucalyptus. TERI had succeeded in creating a sizeable repository of small timber, fuelwood, and fodder. The piece of land that was completely unutilized could be cultivated. It gained an economic value and the villagers felt confident that if auctioned, it could easily fetch Rs 2000/acre. The plantation also succeeded in arresting the spread of salinity into adjoining farm areas. Seedlings from the plantation were supplied to farmers for planting around private farmlands. The plantation also became a source of fuelwood and fodder. The village panchayat also benefited through the sale of thinnings and pruning collected from the plantation. The plantation was of immense help in 1989/90 when a severe drought hit the region and the crops suffered heavy losses. Crop failure meant not only a shortage of grain, but also a shortage of crop residues, which are normally used as dry fodder for the cattle. At this time of crisis, the villagers collected around 300 quintal grass from the plantation site and this helped them to tide over the problem. According to them, if it were not for the fodder collected from the plantation,

The standing woodlot at the plantation

most villagers would have had to sell their cattle during that period, severely affecting the village economy.

Reclamation of private wastelands

Besides the fuelwood plantation, which was taken up on the community land, some efforts were made towards improving the quality of private lands through soil treatment and agroforestry.

While the plantation activities were being undertaken, some farmers suggested that efforts should be made to reclaim individual wastelands as well. Dhanawas had a total of 136 acres wasteland, which constituted 17% of the total land area of the village. Of this, 105 acres was owned by the panchayat and the rest by individuals. These lands had become non-fertile due to the presence of salts and, being in low-lying areas, they often got waterlogged during the rainy season.

Out of the 12 farmers who owned wasteland areas, 4 had made some efforts to reclaim these. They had got the soil tested and had sought advice from government department. They were asked to apply gypsum to the soil every year. However, as gypsum was expensive, none of the farmers applied it. At the request of the farmers, TERI provided technical guidance in reclaiming private lands, which included selection of species and chemical treatment of soils.

Agroforestry

During the initial years of TERI's presence in Dhanawas, some efforts were also made to promote agroforestry. The survey conducted in 1984 was used as a means to introduce agroforestry to the farmers and to ascertain their willingness to practice it in their fields. Pamphlets giving details of agroforestry were distributed. The results were fairly encouraging and a majority of the farmers expressed willingness to try out agroforestry in their fields, showing a preference for fruit trees and trees with good commercial value. Regarding people's willingness to raise a nursery in the village, the survey showed that 32% farmers were willing to lease their land to TERI for nursery development.

A few interested villagers were first taken to nearby villages to show agroforestry plots. Later, five of these farmers planted poplars along with wheat crop in January when the wheat was still very young. The poplar required regular watering and special care during ploughing. Till the harvesting of wheat, the poplars were irrigated along with the crop, but during harvesting, the plants could not be watered as separated channels had not been made for them. Unfortunately, the neglect carried on even after harvesting as the farmers got busy in threshing operations. Also, once the crop was harvested, it became very difficult to protect the plants from the sun. While in other fields, most of the plants died due to lack of water, the survival rate of the plants was not very good even in the fields where they were being irrigated. This could be because of incompatibility of poplars with the soil quality. However, this could not be firmly concluded as no scientific studies were carried out.

School plantation

In 1984/85, tree plantation activity was initiated in the village school. Tree species such as siris, shisham, neem, and eucalyptus were planted. The schoolchildren were actively involved in the planting of saplings. However, these saplings did not survive due to want of water. In 1986, TERI replanted the saplings. By 1988, the school plantation started doing very well. The school teachers and students were actively involved in planting activities such as pit digging, planting of saplings, and watering. Today, the school compound is surrounded by a number of big trees.

VEDC, village dynamics, and the energy plantation

The Dhanawas plantation provides an interesting example of benefit sharing from a common property resource. Of all the projects/programmes carried out in Dhanawas, the management of the plantation was the most challenging. It was affected by the composition of the panchayat and its attitude

TERI staff discussing management issues at the plantation site

towards TERI, internal politics within the panchayat, the outlook of the sarpanch towards TERI's work in the village, etc.

In 1984, when the land lease was negotiated with the panchayat, there was no formal body to oversee energy-related activities in the village. In 1986, when the VEDC was formed, it took the following decisions regarding the plantation.

- The revenue earned from the plantation was to go into the VEDC account and would be used for carrying out general developmental activities in the village.
- The panchayat, in the presence of a TERI representative, would auction the pruning and other output from the plantation (leaves, twigs, etc.).
- The minimum price of the produce (at the time of auctioning) would be decided by the VEDC.
- The residents of Dhanawas would be given priority in the case of outsiders wanting to purchase the produce. They would also be charged a lower price than outsiders.

During the initial years, both the VEDC and the panchayat played a significant role in the management of the plantation. The VEDC decided that all the labour required for the plantation would be hired from Dhanawas only. Initially, members of the harijan community were hired as labourers to plant trees, and each person was paid on the basis of the number of saplings planted. Approximately 40–50 persons (70:30 ratio for men and women) were involved. The VEDC was also instrumental in implementing the following protection measures.

- Prohibition of open grazing in plantation area
- Prohibition of removal of dead biomass from under the trees

- Prohibition of removal of dead branches or twigs
- Permission to cut grass for stall feeding

Over the years, the nature of the VEDC's involvement went through several changes. On some occasions, the villagers did not accept the VEDC's decisions regarding the plantation. There were times when personal interests of influential persons of the village created hindrances in the functioning of the VEDC. The sarpanch always had a prominent role to play in the decisions concerning the plantation. Prior to 1990, the sale from the plantation was not good due to poor quality of wood. In 1990, when the new panchayat was elected, the VEDC decided that the pruning from the plantation would be sold outside the village since no buyers could be found in Dhanawas. The sarpanch, who was not a member of the committee, raised objections. On his insistence, the pruning had to be donated to the village temple.

An important factor that influenced the plantation activities started by TERI was the government plantation raised on an adjacent plot. In 1984, when TERI initiated energy plantation activities in Dhanawas, the panchayat land area was approximately 105 acres. About 80 acres was wasteland unfit for any cultivation. While TERI took 20 acres of this wasteland, about the same time, the government raised a plantation on an adjoining plot of 20 acres. Local species such as *Prosopis juliflora*, *babul*, etc., were raised on the government plantation. However, while TERI continued working on the plantation, the government withdrew its activities in 1990 and handed over the plantation to the panchayat. Soon after, the plantation was cut and the wood was auctioned by the panchayat, which fetched a good value of Rs 60 000. After six years, during which the land was not used for any specific purpose, the panchayat entered into a contract with a farmer for removing the roots and then farming the land for two years. This fetched an additional sum of Rs 7000 for the panchayat. As a consequence, the panchayat also started viewing the plantation raised under the supervision of TERI as a source of income. It thus became a valuable asset for the panchayat, which became interested in cutting the plantation and giving the land on lease for cultivation.

Later developments

In the late 1990s, the land prices in the area increased substantially and a lot of land was purchased for farm houses, private plantations, etc. As a result, the villagers viewed any piece of land in the village as a quick source of income. The earnings from the plantation, at that time, were approximately

Rs 1000 per year. Hence, if the 20 acres were leased out, the returns to the panchayat would be to the tune of Rs 40 000 or more every year.[1] This would be in addition to the one-time income from the sale of wood, which would be harvested from the standing trees. This would amount to around Rs 50 000. The general consensus in the village was therefore to cut the plantation and give it on lease.

Panchayat's stake in cutting the plantation

It was mainly the panchayat members, and in particular the sarpanch, who wanted the plantation to be cut before the next panchayat elections so that the benefits could be accrued by them.

Indifferent attitude of the villagers

The villagers were indifferent to the plantation because they could not see any direct/personal benefit. Also, most families in the village had sold some land in the recent past, thus boosting their standard of living and incomes. They could afford to buy fuel unlike before. Commercial fuels were also becoming more easily available. Most importantly, availability of fuelwood was never perceived as a problem by a majority of the households. Hence, the question of whether the plantation should be cut or not was of little importance to a majority of the villagers.

A few educated and concerned people in the village, who were sensitive to the fact that a considerable amount of time and energy has been spent on the plantation, held a different viewpoint. They were not supportive of the proposal of getting the plantation cut once the lease expired since the trees were not mature and hence, the returns received would be less.

Renewal of plantation lease

The renewal of the lease remained an issue for speculation. While the panchayat would benefit by not renewing the lease, cutting the plantation, and giving the land on lease for farming, there was a section of villagers who opposed it. However, this was more a result of the personal relationship that TERI enjoyed with the people than anything else.

Politicizing the plantation issue

There was a chance that some people might make the cutting of the plantation a political issue in the next panchayat elections. In other words, votes could have been divided and support withdrawn if the panchayat did not renew the plantation lease. It is, however, important to note that at that time the political overtones, which influenced the fate of the plantation, rose from internal conflicts and had little to do with TERI. There had always been different views held by different groups in the village with respect to the plantation. For instance, while one group (sarpanch) wanted the pruning from the plantation to be donated to the temple, there were others who wanted the wood to be auctioned and the money earned to be deposited in the VEDC account.

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[1] In this area, the lease rate for agricultural land is around Rs 2000/acre or higher depending on open auction.

TERI's stand on plantation

Every time the question of cutting the plantation was raised (particularly at the time of lease renewal), TERI had argued that the plants were not ready for harvesting. Hence, the panchayat would not earn much from the plantation. The second point of argument was that the quality of the soil was still not fertile enough for cultivating agricultural crops.

The plantation was handed over to the panchayat before the fresh panchayat elections took place. The panchayat got the trees cut (total biomass production = 548.297 tonne dry weight) and sold them, earning about Rs 60 000 from the sale. Only 2 acres of the plantation area where trees of high commercial value like shisham are growing was left undisturbed as they were still to mature. The land was auctioned for a one-year lease for farming from which the panchayat earned Rs 33 000 in 1998 and about Rs 36 000 in 1999. Bajra, paddy, spinach, tomatoes, and marigold have been cultivated in the area. The growth of the plants is good and the farmer who has taken the land on lease is confident of a good yield.

Plantation area under cultivation

However, there is still a section of people in the village who feel that availability of fuelwood is likely to grow into a serious problem in the coming years, especially for the landless labourers. In this respect, the plantation, if maintained well and conserved, could have been a preventive measure for these oncoming shortages.

Table 2 summarizes the conflicting interests of the various stakeholders in the sale of the plantation.

Table 2 Conflicting stakes of different parties in sale of plantation

Stakeholders	*Stakes*	*Description*	*Action*	*Time frame*
Sarpanch (panchayat)	Monetary	To get the financial returns from the sale of wood	To cut the plantation	Before next panchayat elections
Poor landless households	Monetary	To collect fodder	To let the plantation remain	–
TERI	Non-monetary	To carry out further research To preserve a valuable asset	To renew the land lease	Before June 1999
Other	Non-monetary	To make it a political issue	To withdraw support if plantation is cut	At the time of panchayat elections
Other	Monetary	To get the financial returns from the sale of wood and give land on lease for farming	To cut the plantation and give the land on lease for cultivation	After 2–3 years when trees mature

Conclusion

A majority of the problems faced in the management of the plantation arose because a large section of the villagers remained totally indifferent to the plantation. The main stakeholder was the panchayat, which gained the most from cutting the plantation within its tenure.

From TERI's perspective, the plantation has been a successful experiment for two reasons. Firstly, there has been a marked improvement in the soil quality. Now, it is an asset for the village and a source of income. It also led to the realization among the villagers that such activities can actually be used for improving the quality of degraded land. After seeing the performance of the plantation, the panchayat, on its own accord, has taken up plantation activities on several patches of unusable land in the village. All the wasteland in the village has been brought under plantation.

From a research perspective also, the plantation can be considered a successful project. From TERI's point of view, the primary objective clearly was the reclamation of a highly degraded piece of land by growing appropriate tree species. However in the rural set-up of Dhanawas, as the years went by and the benefits of the plantation became evident, the key stakeholders began to get interested in the benefits they could possibly derive from the plantation. This has led to several conflict situations within the village. There have also been times when TERI was forced to step in and resolve the conflict though it did not really have any stake in the monetary benefits that could be derived from it. In this context, it may be argued that even in projects that are solely research oriented, it is not always possible to delineate the research objectives from the expectations of the people. To this extent, it is important to foresee any spin-offs or unexpected outcomes that the project may generate and set in place systems or mechanisms to deal with such situations as and when they emerge. In the case of Dhanawas plantation, the level of interest that different parties started showing in the plantation once it looked like a potential source of income was clearly unexpected, and both TERI and the VEDC were not fully prepared to handle it.

At the national level, as emphasis on participation of local communities in managing their natural resources grew (as imbibed in the National Forest Policy of 1988), the importance of addressing institutional issues in Dhanawas was also realized (TERI 1994). The need for developing local capabilities and involving women was strongly felt in order to build a closer relation between the community and the plantation. It was also hoped to encourage more farmers to take the responsibility of expanding and managing reclamation of other (private and community) wastelands (TERI 1994). The involvement of people was, however, not forthcoming for reasons mentioned above. It is only logical that for a community to evince sustained interest in protecting forests and forest resources, it is necessary that the forest should be productive in terms of meeting the requirements of the community – for fuelwood, fodder, or timber.

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Chapter 9

Management of technologies: institutional issues

It has long been realized that the issues in rural energy are local and need to be addressed at the local level. The strategy for addressing the core energy problem needs to be area- and situation-specific. One needs to consider the sociocultural diversity and the political reality when planning and implementing strategies. In fact, such strategies need to emerge from the people and the involvement of village communities is critical for sustaining programmes. The involvement starts from defining problems, exploring options, and finding solutions and ways to implement these solutions in order to get the desired results. If the scope of their involvement is extended to evaluating the work done and drawing lessons from the same for improvements in the future, the projects become 'of' the people rather than 'for' them.

It was with this conviction that the participation of the people of Dhanawas was sought. As the activities and scale of projects in Dhanawas grew, it became imperative to organize and institutionalize people's participation. The efforts made in this direction and their effectiveness have been described in the following sections.

Institutionalizing participation

The VEDC was created to 'organize' participation of the villagers, which had till then been on an ad hoc basis. The other objective of creating such a body was to facilitate the planning and management of energy projects and programmes in the village independent of the panchayat. The VEDC was, therefore, given the responsibility of deciding the nature of the programmes and the process of implementation, including selection of potential beneficiaries and controlling finances. A set of rules and regulations was also drawn up to govern the day-to-day functioning of the VEDC. It comprised five villagers including the sarpanch and one person from TERI.

In the beginning, the VEDC was quite active and played a crucial role in several initiatives. For instance, the VEDC was instrumental in identifying the energy programmes that could be taken up in the village. In the case of improved chulhas, the VEDC fixed the price of TARA chulhas and also carried out the distribution of the devices. Likewise, the VEDC selected the households for the demonstration of biogas plants, SWHs, nocturnal water coolers, and solar cookers.

Over the years, the level of enthusiasm of the VEDC members (village representatives) and their involvement in energy activities dropped considerably. For instance, the VEDC did not prove to be a very effective body for conflict resolution. On many occasions, its members were hesitant to interfere in any dispute or get involved in polemic issues of any nature. This was more on account of their personal relationship with the villagers than the problem as such. Though the members provided many suggestions at the meetings, the efforts necessary for their implementation were not always forthcoming. There were several instances where the VEDC did not show any initiative to tackle problems. To give one example, when the first biogas plant was installed in the village, the owner was a bank loan defaulter and could not get another loan from the bank. The Institute had to meet almost the entire plant cost. Later, the owner got a subsidy from the government, but did not return the amount to TERI. The VEDC's help was sought in this regard. However, all efforts to make the committee members persuade the plant owner to pay the money failed as the members were reluctant to get involved in any controversies.

The other problem experienced was that some villagers, who often were not members, would use the VEDC meetings as an opportunity to settle their personal disputes or merely discount a decision to settle a personal score. This adversely

Members of the Village Energy Development Committee at TERI's New Delhi office affected the proceedings of the meeting and many would end in chaos without any decisions being taken. The committee did not prove effective in solving problems like arranging for labour for plantation work or negotiating with the labourers on the issue of wages. Difficulties were also faced in seeking cooperation from the villagers on getting a piece of land for raising a nursery or ensuring the protection of the plants planted in the school compound.

In effect, at any point in time, there were only one or two persons in the VEDC who were enthusiastic and keen to support TERI. The rest of the members remained passive and only mildly curious of what TERI was doing. Even within the village, the committee was not a well-known body. The AIUN survey showed that while all the households were aware of TERI's activities, only 37% knew of the VEDC.

At the time of setting up the VEDC, it was decided that there would be at least one woman representative. When the VEDC was constituted for the first time, most of the members were from the panchayat. At that time, there was already a woman in the panchayat, who was included in the VEDC. It was envisaged that the presence of a woman in the meetings would help raise issues important to women and also make it easier to get other women involved. However, except on a few occasions, the presence of the woman member in the VEDC remained symbolic in nature. This was a result of the sociocultural norms and values, which did not permit women to voice their opinion in front of men. Interestingly enough, the same women who would not utter a word in front of their men folk would discuss openly when separate meetings were held with them. They also had no hesitation in speaking their mind in front of the TERI project staff, even though a number of them were men.

Support of key individuals

Some villagers were always supportive of the Institute's efforts in their individual capacity irrespective of whether they had any share in the benefits or not. They actively participated in all events/meetings and programmes initiated in the village. They helped the Institute to build rapport with the rest of the village by acting as 'contact' persons. They also extended their cooperation by organizing the villagers, at least their acquaintances, during times of important decision-making. However, most of these people contributed to the work in their individual capacity rather than as 'leaders' of groups/community. They also stayed away from any controversies or were aloof whenever there was a conflict of ideas/interests.

Role of village institutions

The panchayat is undoubtedly the most important decision-making body at the village level. For external agencies working in the field of rural development, local institutions like these play an important role. They can serve as catalysts of development and play a proactive role in any developmental activity. In the rural set-up, the panchayat also provides the necessary sanction to an 'external' agency to be able to work in the village.

When TERI started working in Dhanawas, initially all the activities were carried out through the panchayat. It also played an important role in helping TERI to understand the actual village scenario and the needs of the people, and identify appropriate interventions for the village. Though one of the objectives of setting up the VEDC was to delineate energy activities from the village politics, the panchayat always influenced the functioning of the VEDC and TERI in the village. At the time of setting up the VEDC, a written approval was obtained from the panchayat regarding the formation of such a committee, its members, and charter of duties. It was decided that the sarpanch would become a member of the committee as it would not only provide a formal sanction to TERI's activities in the village, but also expedite matters. It was also expected to ensure an automatic flow of information between TERI and the panchayat and encourage the latter to take up developmental activities in the fields of energy and environment. However, the political changes, especially in the village leadership, greatly influenced the work strategy of the Institute.

The first panchayat election after TERI made an entry in Dhanawas was held in 1986, which was the year the VEDC was formed. The sarpanch was quite supportive of TERI's activities. The next panchayat election, which was held in 1988, saw the re-election of the same person as the sarpanch. In the following elections in 1991, a new sarpanch was elected. Following this, the VEDC was reconstituted and the newly elected sarpanch became a member of the VEDC. The next panchayat elections in the village in December 1994 also resulted in a change in village leadership and a reorganization of the VEDC. The new sarpanch was given membership and the size of the VEDC was increased from seven to ten.

A change in village leadership, therefore, was always accompanied by re-election of the VEDC. The sarpanch automatically became a member, while the old sarpanch ceased to be a member. There were also times when the sarpanch saw to it that some of his close associates too became members. This influenced the village dynamics greatly and affected TERI's relationship with the villagers, which, in turn, had an impact on the ongoing activities and the planning of future programmes.

In retrospect, it may be argued that at times like these, TERI's intervention could have possibly helped to avoid such power play. However, TERI had decided not to get involved in local politics and encourage the villagers to take all decisions. TERI staff was to give counsel and opinion only when solicited for. This stance of the Institute severely affected the distribution of benefits, which led to numerous problems like in the distribution of the solar systems. Even in the case of the energy plantation, undue pressure was put by the sarpanch and his family to get the plantation cut during his tenure.

People's perceptions about TERI

The role of TERI in the village had always been multi-fold. Though the objective of the Institute was to carry out field-based research on energy, the project staff had to play a variety of roles in response to the demands and expectations of the villagers. In fact, drawing a line between what TERI should and should not do in Dhanawas was always difficult. To what extent the project team should get involved in non-energy related activities was an issue the field staff faced throughout their work. Over the years, TERI worked as an initiator, facilitator, supervisor, and technical expert on energy technologies. The people also viewed the Institute as a source of funds and potential financier of developmental activities. Throughout its work in Dhanawas, the villagers also called upon TERI staff to resolve conflicts and help them in times of crisis. On its part, the Institute also undertook certain tasks/responsibilities only to oblige the people. This was considered important for rapport building since energy was not the priority of the villagers.

With time, the people's confidence in TERI grew. TERI staff was consulted on matters of all kinds, from energy interventions to disputes over land. However, this understanding with the people had a negative side as well. During the later years, a few local leaders began to resent the relationship the TERI staff had with the villagers and began to feel threatened. The sarpanch once objected to TERI calling for a village meeting. On several occasions, the sarpanch made clear his reservations against TERI's role in the village and conveyed that the Institute should have no say in village matters. This led the Institute to re-examine its role in the village and take some firm decisions in this regard. It was decided that no new activity would be initiated in the village unless the people approached the Institute. It was also decided that no device or service would be offered henceforth free of cost. The beneficiaries would have to pay a certain amount fixed by the VEDC. Also, the Institute started planning a gradual withdrawal from the village.

The changes occurring in the Indian economy also affected the villagers. For rural India as a whole, the exposure to market economy has been on the increase since the early 1990s. Thanks to the media and active advertising by companies, the villagers are being flooded with consumer goods and the lures of consumer durables like never before. Because of its proximity to Delhi and Gurgaon, these changes have been far more rapid for Dhanawas compared to villages in the interiors. The village, which had just one or two television sets a decade before, can now boast of a set in every household. In sharp contrast to just a decade back when the acquisition of agricultural land was the ultimate dream for a farmer, purchasing a TV or a car has become more important now. The desire to acquire consumer durables has, in a way, affected the functioning of TERI in Dhanawas. The pressure on TERI to work on areas other than energy increased with time.

The gap between the expectations of the people and the mandate of the Institute thus grew. The Institute had a fixed mandate to develop and demonstrate technologies so as to meet the village energy needs in a sustainable manner. Despite repeated efforts of the Institute to clarify its R&D objectives, the people expected that the Institute, with its affiliation to the Tatas, would provide employment opportunities or improve village infrastructure. With no shift in the Institute's objectives, it perpetuated a degree of disinterest or indifference among the people.

Other institutional issues: organizational changes within TERI

The 15 years of work in Dhanawas was also a period of changes within TERI. During these years, the Institute grew not only in terms of numbers, but consolidated its past achievements and ventured into new research areas. As most of the project team members had been involved in theoretical or lab-based research before, rural action-oriented research in Dhanawas posed many challenges for them. As it happens with any institution, except for a core group of people who were involved throughout, the composition of the team also changed as people left and others joined. This change proved to be a source of strength as each new person brought with him or her new concepts, methodologies, and ideas that they were keen to test and this lent the work in Dhanawas considerable dynamism. At the same time, this caused a degree of instability at times, as the new persons had to familiarize themselves with the surroundings and also invest time and effort in building a rapport with the villagers.

Another factor that influenced the work in Dhanawas was the composition of the project team and the research agendas of different groups which worked in Dhanawas. As mentioned earlier, the main objective of intervening in Dhanawas was to work out a mix of technologies/interventions that would be appropriate in a rural set-up and would lead to sustainable energy consumption patterns at the village level. Depending on the area of expertise and the technology involved, at any time, there were at least two to three groups of researchers from a particular discipline working in the village. There was one group of professionals developing the TERI biogas model in Dhanawas who later worked on the biomass gasifier. There was a separate group of professionals looking into the chulha programme, and there were some forestry experts working on the energy plantation. Each of these groups had a particular 'research objective' to fulfil. The focus was clearly on technology development and testing the appropriateness of the technology under local conditions. In this endeavour, Dhanawas served as a testing ground for field-based research.

A re-examination of the experience suggests that probably not enough attention was given to the institutional and management aspects. The formation of the VEDC was a definite attempt towards giving the villagers final decision-making powers regarding TERI's role and involving them in energy development activities in the village. However, it achieved only partial success. It may be argued that the factors responsible for the limited success of the VEDC were germane in the societal set-up and as such outside the purview of TERI's activities. However, the fact remains that several management problems arose during the course of work which neither TERI nor the VEDC was able to resolve. It may also be said that during the initial years, when the technological interventions were in their infancy, it was only logical to direct all efforts towards refining the technologies, improving the performance of the devices, and making them appropriate for dissemination in a rural set-up. The seriousness of management-related issues such as village dynamics and local politics arose only after the interventions had reached a certain degree of maturity and the benefits became visible and apparent to the village community.

Figure 1 is a graphic representation of TERI's role vis-a-vis the village institutions.

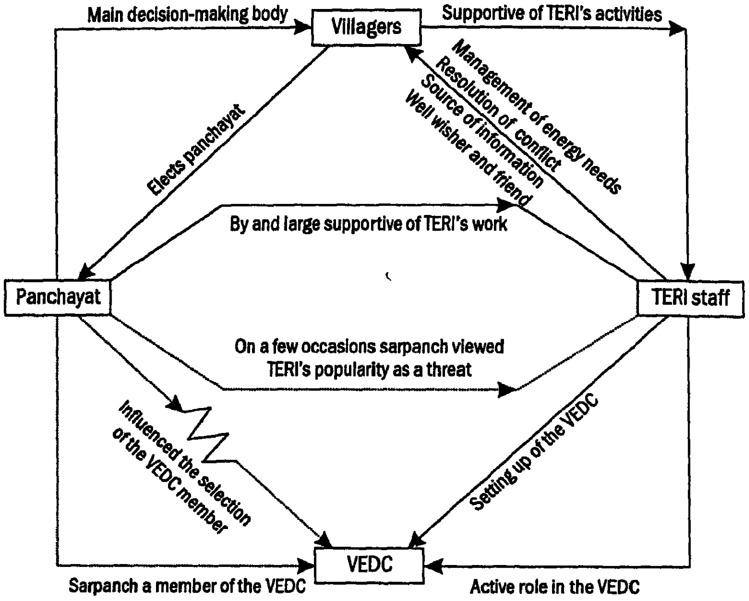
Main decision-making body
Villagers
Supportive of TERI's activities
Elects panchayat
Management of energy needs
Resolution of conflict
Source of information
Well wisher and friend
By and large supportive of TERI's work
Panchayat
TERI staff
On a few occasions sarpanch viewed TERI's popularity as a threat
Influenced the selection of the VEDC member
Setting up of the VEDC
VEDC
Sarpanch a member of the VEDC
Active role in the VEDC

Figure 1 TERI's role vis-à-vis village institutions

Conclusion

In the initial stages, people's participation was not seen as complementary to the objectives of technology development and demonstration. To be able to make an entry into the village, approval of the panchayat was necessary. The need for a formal body to manage these activities was recognized only after some time. This approach only perpetuated dependency among the people and they felt that the Institute was under some compulsion to develop them. This gave them the upper hand and they took to bargaining with the Institute, collectively or individually.

The clash between the R&D objectives of the Institute and the expectations of the people could never be satisfactorily resolved. As time progressed, the scale of activities increased. On the other hand, the needs and aspirations of the people changed. Their desire for material well being and quick gains increased the pressure on TERI to involve itself in developmental activities other than energy.

With increase in TERI's credibility in the village, the village leadership felt threatened and conditions were so created that withdrawal from the village was deliberated upon. This was not easy for the Institute as the modalities of disengagement had not been considered in the initial stages itself. The issue of how to withdraw from the village was discussed after 15 years of working in the village. Had the institution-building aspects been considered in the initial stages, a smooth withdrawal could have been ensured.

Chapter 10 Evolution of overall strategy

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Dhanawas today is a fast-growing village with strong urban linkages and is representative of a large number of villages that can be termed as peri-urban rather than rural. Fifteen years of work in Dhanawas has been of immense learning value for TERI. It also brought out certain possibilities that can be pursued at the national level by formulating appropriate policies and programmes.

Over the years, several technologies have been introduced in Dhanawas, some of which have been accepted well and are today an integral part of the energy system of the village, while certain others were inappropriate for rural applications. There have been essentially three components of work in Dhanawas.

1 To demonstrate and develop renewable energy technologies at the village level.
2 To set in place institutional systems at the local level for the management of these technologies.
3 To build local capacity to sustain the energy development activities after TERI withdraws from the village.

In retrospect, the 15 years of action-oriented research experience in Dhanawas can be divided into four distinct phases.

Inception and rapport building

For TERI, the first phase of the village-level work focused on trying to understand the energy scenario in a rural setting. After TERI decided to initiate work on rural energy issues, the first requirement was to develop an understanding and appreciation of issues pertinent to rural India. During this period, the activity in Dhanawas primarily involved rapport building and informal discussions with the villagers. Detailed studies were also made of energy surveys carried out by other institutions in the past. TERI carried out its first energy survey in Dhanawas in 1984 with the objectives of understanding and documenting the existing energy consumption pattern to project energy demands in the future and clearly identify the energy needs of the village.

Technology demonstration and development

The inception phase was followed by a period during which a number of technologies such as the biogas plant, improved cookstove, and biomass gasifier were developed and field tested. This period extended over several years. Experimental work on reclaiming degraded land through soil treatment and energy plantations was also initiated. The focus of all the activities was on testing renewable energy technologies in a rural setting and modifying them to suit the specific requirements of the villagers. During these years, besides actual technology development, the TERI team had to invest considerable time in motivating the villagers to participate in the process. This, at times, proved to be difficult primarily because the villagers were either not convinced or not familiar with the benefits of these technologies. As a large number of Janata plants, installed in the early 1980s, had failed, people had little faith in the technology. Biomass gasifier was a completely new concept for the people. Some of them had seen and heard about improved chulhas, but no one in Dhanawas had any previous experience of using them. Most villagers were indifferent towards the plantation for they saw no direct gains. Several other technologies like the solar water heaters and solar cookers were also field tested. They were dropped when found unsuitable for the village.

During this phase, the VEDC was also set up with the objective of enhancing the participation of the villagers in energy development activities.

Technology acceptance and capacity building

The third phase of the work began when the people started accepting some of the technologies. By the late 1980s, the village had several biogas plants performing to the satisfaction of the users. The people also appreciated improved cookstoves, especially the Nada chulha, and many women expressed willingness to adopt them. During this period, TERI was able to establish credibility in the village, and the people of Dhanawas began accepting TERI staff as a part of the village. People started involving the TERI project team in their decisions, approaching them for resolving internal conflicts, and the women began to interact freely with the project team, which comprised chiefly men. During this period, the village was visited by a number of important guests, which further increased the exposure of the villagers to the outside world.

After technologies like biogas and improved chulhas reached a threshold level of maturity in the village, the technology demonstration phase began to take the shape of a 'programme' or the dissemination phase. As the number of devices grew, mechanisms for the maintenance of the systems had to be set up. The need to set in place management systems also arose during this period.

An important development during this phase was that for the first time village politics began to affect TERI's functioning. The Institute realized that it would not be possible to remain isolated and indifferent to the village power play. This further heightened the need for setting up local, community-based management systems.

Capacity building was also taken up during this phase, wherein concrete steps were taken to develop the people's skills so that they could plan, design, and install renewable energy technology devices according to their needs. A series of training programmes for the construction of improved chulhas and biogas plants were organized, in which both men and women participated enthusiastically. Some of the masons also constructed biogas plants in other villages around Dhanawas and in other areas where TERI projects were going on. Training sessions on maintenance of improved chulhas and biogas plants were also organized periodically to equip users to identify and rectify minor defects in these devices.

Figure 1 outlines the energy development activities in Dhanawas.

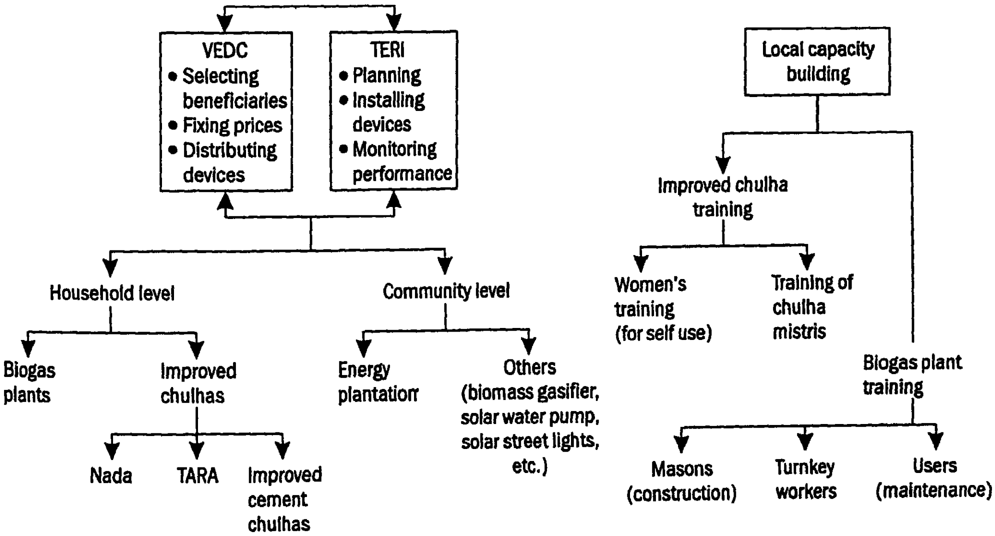

Figure 1 Energy development activities in Dhanawas

Withdrawal

The final phase (1998/99) was the gradual withdrawal of TERI's presence from the village (Table 1). This involved setting in place requisite systems that would ensure a smooth withdrawal and handing over the management of the technologies completely to the villagers. The strategy of TERI in the withdrawal phase had three distinct elements (Figure 2). Firstly, dissemination of technologies for which there still was a demand (improved cement chulhas and biogas plants) was continued for a year. However, even in these, the bulk of the work was carried out by the persons trained within the village, with TERI assisting only in terms of providing technical guidance. For these technologies, the area of operation was also expanded to other villages around Dhanawas.

Table 1 Activities taken up during the withdrawal phase

Technology/ device	*Activity*	*Monthly*	*Quarterly*
Improved chulhas	Monitoring	Functionality of devices	Physical inspection of the devices
Biogas plants	Monitoring	Functionality of devices	Physical inspection of the devices
Solar photovoltaic lighting system	Technical back-up and monitoring	To assess the functionality of the devices and oversee the coordination between users and technicians	Physical inspection to check the level of performance
Plantation	Conducting test on soil quality and measuring yields	–	–

The second element of the strategy pertained to technologies that were for community use – the solar water pump and the plantation. The latter was handed over to the panchayat. A locally managed distribution system was set in place for the solar water pump so that its utility could be maximized. It was decided at the Institute level that, till the end of 1999, only such activities would be initiated in the village that are

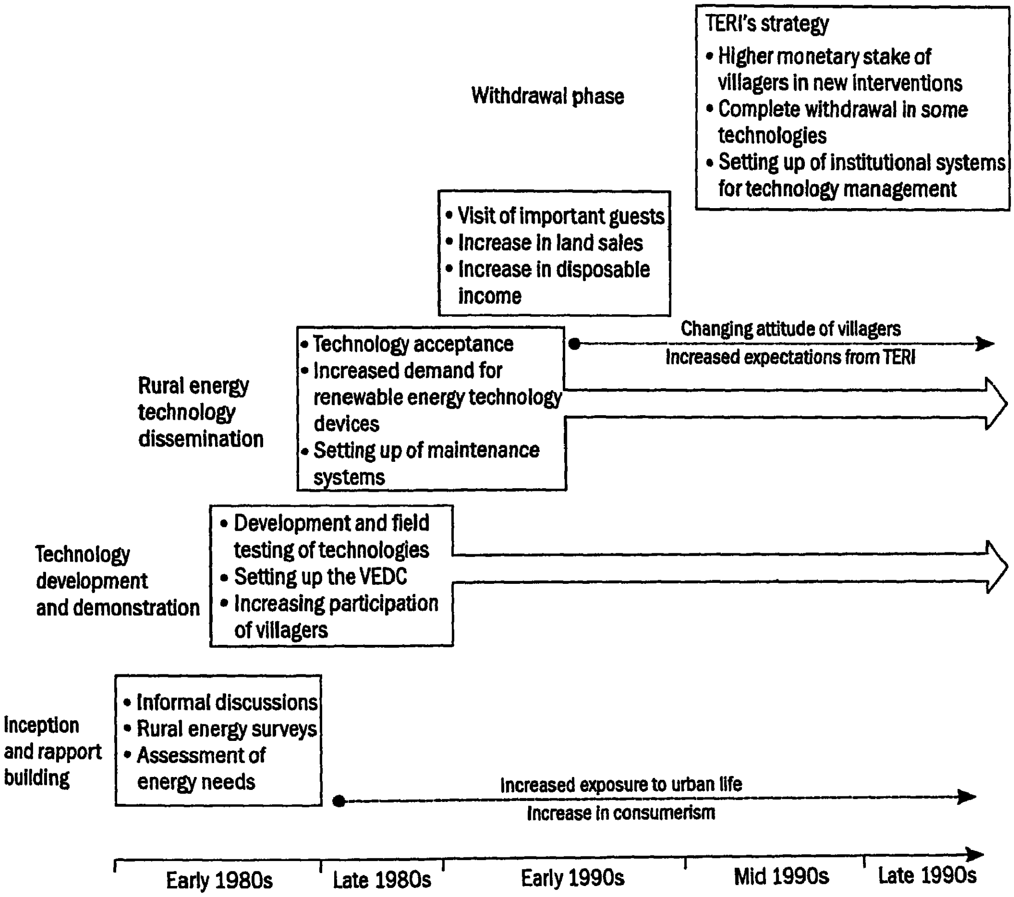
TERI's strategy
• Higher monetary stake of villagers in new interventions
• Complete withdrawal in some technologies
• Setting up of institutional systems for technology management
Withdrawal phase
• Visit of important guests
• Increase in land sales
• Increase in disposable income
Changing attitude of villagers
Increased expectations from TERI
Rural energy technology dissemination
• Technology acceptance
• Increased demand for renewable energy technology devices
• Setting up of maintenance systems
Technology development and demonstration
• Development and field testing of technologies
• Setting up the VEDC
• Increasing participation of villagers
Inception and rapport building
• Informal discussions
• Rural energy surveys
• Assessment of energy needs
Increased exposure to urban life
Increase in consumerism
Early 1980s
Late 1980s
Early 1990s
Mid 1990s
Late 1990s

Figure 2 Development of energy intervention strategy over the years

completely need-based. These activities had to fulfil the following criteria.

- The demand must come from the villagers.
- The villagers must have a monetary stake in the installation, maintenance, and repairs.
- The villagers must take complete responsibility of the upkeep and maintenance.

Accordingly, when the water distribution system was designed for the village, the beneficiary households were asked to pay for the services being offered. This strategy was adopted in consultation with the members of the VEDC and the panchayat. It was decided that whoever wanted to avail of the benefits of the SPV pump would have to make a monetary contribution to meet the cost towards the installation of the water tank. The panchayat also contributed partly towards the purchase and installation of the tank. The cluster of households that contributed money for the tank site has taken the responsibility of ensuring its maintenance. The protection of the pump site and its smooth functioning has been taken up by the panchayat.

It was also decided that TERI would withdraw completely from technologies where there is no distinct advantage in continuing activities (from an action-oriented research point of view for TERI, and in which the villagers have no interest). Till the end of 1999, the performance of the devices, functioning of the VEDC, and management systems designed to support the interventions were monitored.

Chapter 11

Implementing the Dhanawas experience in other areas

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By 1992/93, TERI had completed almost a decade's work in Dhanawas. These years witnessed changes in the energy policy at the national level. There were large-scale demonstrations and popularization of several renewable energy technologies such as SPV, small hydro, and wind power generation. For an organization like TERI working on sustainable energy options, this period was one of expanding its activities, diversifying into new areas, and taking stock of and consolidating past experiences. The continuous presence and activities in Dhanawas provided important insights into the nature of rural energy issues and valuable lessons in action-oriented research and dissemination of renewable energy technologies. The withdrawal phase was one of introspection and critical analysis of the experience, attempting to synthesize and internalize the learning and carry it into planning future activities.

Role of women in domestic energy system in rural India

In 1992, the Rural Energy Group at TERI started work on participatory rural energy planning with the focus on designing an appropriate intervention package for the cooking energy system that can be used both by the people and the planners at the local level. The project, entitled 'Role of women in domestic energy system in rural India', was funded by the Shastri Indo-Canadian Institute and was carried out by TERI in collaboration with the University of Waterloo, Canada. Unlike the earlier studies that focused on technology development, the aim of this study was to develop and use a holistic concept of quality of life in relation to the cooking energy system, based on the perceptions of rural women.

The need for such a project arose from the realization that the poor involvement of women in rural energy programmes is one of the important reasons for their unsatisfactory performance. Women play a central role as the producers, processors, and traders of biomass resources. They are also the designers and users of stoves that are used to cook food for the family. The impacts of a fuel shift are, therefore, particularly severe for rural women who are forced to spend more time gathering fuel or to switch to low-grade fuels.

Even though researchers recognize the central role of women, most research in this area focused on rural energy patterns, designing and demonstrating interventions, and evaluating the impacts of these interventions. Typically, the role of women is restricted to that of beneficiaries or data sources. Women are involved in energy programmes only when new technologies or devices are to be used or to convince other women to use them. There is a lack of appropriate planning tools and other wherewithal to incorporate the role of women in the planning process itself.

The problem in involving rural women in energy planning was encountered on several occasions during TERI's work in Dhanawas. In fact, except for the improved chulha programme, where women were trained as chulha mistris, they could never really be involved effectively in planning programmes. Though the VEDC always had women representatives, their role as decision makers was insignificant. This was because no formal tools were employed for actually enhancing their role in the planning process. The approach was limited to informal mechanisms like discussions with women at different stages of the project or trying to convince the men to encourage women to participate. The Shastri project, which was a response to this need, proposed to address this problem by conducting a detailed micro-level investigation in a few selected villages and developing tools and techniques to (1) increase the role of women in rural energy planning, and (2) evaluate the appropriateness of choices.

The project

The research project was based on the premise that involving local women in the design and implementation of energy interventions, particularly in the cooking energy system, can enhance their effectiveness. To achieve this, the project involved an in-depth study of the role being played by women in the domestic energy system in specific villages of Faroukh Nagar block, Gurgaon district, Haryana. Based on the findings of the study, an appropriate intervention package and dissemination strategy was designed to enable women to play a decisive role in cooking energy programmes. This broad aim was operationalized into the following specific objectives.

- *Research objective.* To develop a conceptual framework for understanding the role of women in the domestic energy system in rural India and the application of the 'systems theory' to understand the structure and functioning of this system.
- *Development objective.* To develop a methodology for designing interventions in the rural cooking energy system with

the involvement of local people, especially women. This objective was further broken down into the following specific operational tasks.

- To design an alternative cooking energy system based on the knowledge and understanding of women of their local environment and traditional systems, their perceptions with regard to their felt-needs and developmental priorities, and reasons for willingness or resistance to change.
- To generalize this experience to develop guidelines for designing alternative cooking energy systems with enhanced participation of women.
- To develop a set of tools and techniques to elicit women's participation at all stages of the project.

- *Institutional objective.* To try out an innovative approach to decentralized rural energy planning and to synthesize the learning from the project and the past experiences in the field into guidelines for providing policy support.

Project tasks

During the course of the project, there were intensive interactions with the villagers, especially women, over long periods of time to gather their perceptions on the cooking energy system. Methodology development was an important part of the project. There were two major components in the micro-level study. The first was to conduct research in areas where interventions had been undertaken or were operational. The main purpose of this research was to find out how various stakeholders perceived the project. This was done to understand the qualitative aspects of project management – whether the project benefits were made clear to the participants, their level of willingness to change and participate in the programme, whether women felt that they were adequately consulted and that their ideas were valued, etc. The second component of the project involved the actual designing of an energy intervention for a village with the active participation of women, documenting the process extensively, and synthesizing the learning into specific guidelines.

For the first component of the project, the biogas programme in Gurgaon district was selected. In the 1980s, the biogas programme was implemented on a large scale in Haryana. Under this programme, mainly large plants (6-cubic-metre capacity) were installed. A study was conducted in 27 villages of Faroukh Nagar block to understand people's perceptions of the biogas programme. Eighty biogas plants were inspected. The owners were interviewed in order to examine the performance, problems faced, and the present status of the biogas plants. Information was gathered on the number of cattle, capacity and type of plant, commissioning details, functional status, problems faced, complaints made to the implementing agency, remedial action taken, willingness to undertake repair work, etc. Other information included location of the plant, availability of water, location of kitchen, and number of family members.

After developing a basic understanding of this programme, the next step was to identify villages for the in-depth study of the energy system and programmes. The project began with the collection of secondary data about the region, based on which appropriate criteria could be developed for identifying villages for further study. Data were collected from the block and district headquarters on (1) various aspects influencing energy consumption pattern and (2) government programmes. Analysis of this data helped in the initial short-listing of villages, which were then taken up for a preliminary survey through structured questionnaires. The survey, however, was abandoned midway as it was felt that quantitative data did not yield information on important parameters like willingness of the people to participate in the project and the perceptions of women on energy-related issues. It was then decided to hold open-ended discussions (with focus on energy) in the short-listed villages. Interviews were conducted with groups of men and women separately in order to document variations in opinions on issues and how important the issues were to each of the two groups. This also provided an opportunity to evaluate the past programmes and their impact on the lives of the people. The discussions were also intended to reveal the extent of the villagers' interest and willingness to participate in future activities. The involvement and the time commitment of the villagers in the process were important for getting a proper insight into the issues. Fifteen villages were short-listed in the process. Considering the objectives of the project, it was decided to classify/identify villages in the following typologies and select at least one village in each of these categories.

- Villages where dung cake could be replaced with briquetted fuel.
- Villages without any history of government programmes in the energy sector.
- Villages where the dissemination of biogas technology had been unsuccessful (represented by number of dysfunctional plants in the village), but which appeared to have potential for biogas plants.

- Villages that had a potential for possible intervention in the cooking energy system (like improved cookstoves, biogas, and energy plantations).

Based on field visits and interactions in the short-listed villages, the following villages were identified for further research work.

- Gari Natthe Khan, where biogas and improved chulha programmes had been run by the government a few years back. However, very few devices were still in use.
- Sultanpur and Tajnagar, where family-size biogas plants had been installed, most of which were defunct.
- Dhanawas, where a biogas programme run by TERI had received high acceptability and the majority of plants were functioning satisfactorily.

A different set of activities was carried out in each of these short-listed villages over a two-year period. For example, in Gari Natthe Khan, the focus of research was on developing an energy plan for the village, with the active participation of women. The final output of the exercise was a village energy plan that the villagers developed, with TERI only playing a facilitating role. In Sultanpur and Tajnagar, the task consisted of repairing biogas plants which had been lying defunct for several years and assessing any attitudinal change that this exercise brought about in the minds of the people regarding biogas technology. The third task consisted of carrying out an impact assessment of the biogas programme in Dhanawas in order to understand the factors that have contributed to the success of the programme in the village. It was also intended to understand the differences in the perceptions of men and women regarding the technology.

As the final output of the project, intervention plans were developed for the cooking energy sector in these villages. The entire process was documented in the form of guidelines for developing such local packages. These guidelines have been brought out in the form of a handbook on participatory rural energy planning. The objective of this handbook is to provide a concise set of guidelines for participatory planning in rural energy programmes. The handbook presents an analytical framework and a detailed methodology for participatory planning in the rural energy sector. It also gives the tools and techniques for making this planning process truly participatory.

Project on fuel substitution in rural areas

In 1995, TERI initiated its first implementation project titled 'Fuel substitution in rural sector'. The project was supported by the Indian Oil Corporation Ltd and the Gas Authority of India Ltd. The broad objectives of the project were to (1) devise and implement pilot-scale rural energy projects based on renewable energy and energy conserving technologies and (2) to conserve kerosene and firewood, in selected villages in three districts of the country representing different agro-climatic zones and socio-economic conditions.

This was a pilot-scale demonstration project for which three districts representing different agro-climatic zones of the country were selected (1) Solan (western Himalayan), (2) Sultanpur (upper Gangetic plains), and (3) Jaisalmer (western desert region). These also represented varying social, cultural, and economic conditions as well as typical energy systems. Some of the salient features of the project were as follows.

- *Decentralized planning and implementation.* The local population was involved through village-level institutions such as the panchayat, mahila mandal, and local NGOs. They were involved at all stages of planning, implementation, and monitoring of the project. This in turn helped in capacity building, enabling them to undertake such activities independently in the future.
- *Creation or provision of repair and maintenance infrastructure at the local level.* This was done by training local technicians or entering into local maintenance contracts with the manufacturers.

Solar lantern service centre: enhancing income generation, Jaisalmer

- *Development or improvization of technology to suit local requirements.* Emphasis was laid on adopting available technologies or improving the technology to suit local requirements by continuous monitoring of the installed devices.

During the project, almost 1000 households located in about 35 villages were covered. However, the main activities were concentrated in 12 villages (4 in Jaisalmer, 5 in Solan, and 3 in Sultanpur). After selecting a cluster of villages in each district, surveys were conducted to gather information on the energy consumption pattern, resources available, and information on social, economic, and cultural aspects. Based on the results of this survey and parameters like development priorities of the people, technologies, and infrastructure available, the focus areas for energy interventions in each of the three districts were selected – in Solan, water heating and cooking; in Jaisalmer, lighting; and in Sultanpur, cooking and lighting. In-depth discussions with the villagers and representatives of village-level institutions like the sarpanch and panchayat members were helpful in assessing (1) the development priorities of the people, and (2) managerial capability and leadership in the village to implement the plan and look after the maintenance of the systems installed. In cases where appropriate technology options were not available, development and field trials of technologies were taken up. Energy intervention plans based on renewable energy like biogas, solar water heating, solar cooking, and SPV lighting and home systems and energy conserving devices like improved chulhas and improved kerosene lanterns were implemented. Table 1 provides the key components of the implementation plan.

Table 1 Key components of the implementation plan

Project area	*Area of focus*	Devices	Number
Solan	Water heating and cooking	Community solar water heaters (750 litres per day)	3
		Improved chulhas	116
		Solar cookers with electric back-up	51
Jaisalmer	Lighting	Solar lanterns	275
Sultanpur	Cooking and lighting	Biogas plants	24
		Improved chulhas	250
		Improved kerosene lanterns	500
		Solar lanterns	65

Masons constructing a biogas plant in Sultanpur

The energy plans were implemented in collaboration with local institutions or individuals. Training programmes were organized for the partners involved in the implementation process, for example training of masons in biogas construction in Sultanpur, training of women in improved cookstove construction in Solan, and training of women in the operation and maintenance of solar lanterns in Jaisalmer. To the extent possible, already existing local institutions were utilized for executing the project. In Jaisalmer, village committees having 2–5 members were formed to collect monetary contributions from the villagers and help TERI in the implementation; in Solan, the existing institutions of mahila mandals were mobilized for the operation and maintenance of the community solar water heating system.

Different approaches were adopted for project implementation in the three areas (Table 2). For example, in Sultanpur, the activities were run more or less on the lines of the government rural energy programme. However, more emphasis was given to maintaining the highest quality during the purchase and construction of the devices/systems; involving local people in all phases of the project; and training local technicians in the construction, operation, and maintenance of the devices. This was done in order to build local capacities, which is essential for making such initiatives sustainable.

The masons and turnkey workers who had been involved in the biogas programme in Dhanawas executed a large component of the biogas plant construction work in Sultanpur. For these masons, it was an opportunity to further strengthen their skills.

Table 2 Main features of the implementation strategy adopted in Sultanpur, Solan, and Jaisalmer

Project area	*Implementation*	*Status of technology*	*Subsidy level*	*Maintenance*	*Monitoring*
Sultanpur (Uttar Pradesh)	TERI with the help of local trained manpower and some assistance from the village panchayat	Only well-proven technologies were used	Very high - 90% in most of the cases	Individual beneficiary with help from local technicians	TERI
Solan (Himachal Pradesh)	TERI with the help of local institutions like NGOs, village panchayat, and mahila mandals	Development of improved chulha in collaboration with local NGO and villagers Other technologies were commercially available	Moderate for individual systems (60% to 80%), very high for community systems (90%)	Local institutions	TERI with the help from villagers
Jaisalmer (Rajasthan)	TERI with the help of locally trained technicians	Field testing of solar lanterns Some improvements carried out in the solar lantern circuit	Very high (90%)	Village committee and local technicians	TERI

In Solan, the NGO implementation model, which had a totally decentralized approach, was adopted. All the activities, from the development of a new design of improved chulhas to implementation, were carried out by local NGOs and village institutions like panchayats and mahila mandals, with TERI playing a supporting role.

- *TERI.* As an external agency, TERI took the help of a local NGO to make an entry into the village community. As an institute, it provided its managerial skills and technical expertise to the intervention. In turn, it depended on the knowledge and understanding of the local people, especially women. Based on this knowledge, the Institute worked on improvements in the traditional system, as desired by the people, to bring about a beneficial change. It relied on local innovations for improvements in traditional devices.
- *NGO.* As a local-based organization, the NGO served as an important link between TERI and the people. It played a significant role in developing new designs of cookstoves and framing the strategy for disseminating these devices. This, in turn, built their capacities – technical and managerial – to handle rural energy projects.

- *Women*. As the traditional designers and ultimate users of the technology, the women were not only the 'information providers', but co-partners in the designing and implementation of the intervention. They provided insights into the positive features of the traditional devices, which they would want to retain, and the improvements that they thought were necessary. This feedback was vital for designing technologies that had more chances of being accepted.

Further, participation of the people in technical monitoring and dissemination and evaluation of the programme also played an important role in designing sustainable energy programmes.

In Jaisalmer, a local NGO working in the area was involved in the beginning. However, due to logistical problems, it pulled out of the project. Later on, the place of the local NGO was taken up by the village committees, which were formed specifically for this purpose. The committees were entrusted with the task of collecting monthly charges from the villagers and, in turn, they were made responsible for maintaining the systems. This, however, did not work and a system of individual entrepreneurs servicing the devices was put into place.

The key feature of the programme in Jaisalmer was the setting up of a local maintenance support system. A 3-tier system was set in place, involving the following.

1 Village-level groups called village committees were created. They were made responsible for small repairs like fuse replacement and loose connection.
2 A semi-skilled technician visited each village on prefixed dates every month to carry out minor repairs like replacement of lamp and PCBs (printed circuit board).

Villagers with solar lanterns in Jaisalmer

3 A skilled technician who was based at the district headquarters was identified for carrying out major repairs.

Conclusion

The action-oriented research done in Dhanawas led to a deeper understanding of the rural energy system and the relevance of sociocultural factors that have to be considered while planning programmes with the people. This learning was incorporated in future projects. The objective of these follow-up projects was to design tools/methodologies for working with the people and, therefore, develop workable models. TERI's work in Sultanpur, Solan, and Jaisalmer established the replicability of these models/strategies. A major focus area of the Institute has been involving NGOs and building their capacities to plan and implement rural energy programmes based on renewable energy technologies. There is a need for designing more such workable models for planning and implementing rural energy programmes with people in different agro-climatic and social conditions. Also, the tools for facilitating participation need to be continuously tested for their applicability and new ones need to be designed.

Chapter 12 Lessons from Dhanawas

Rural energy matters: the Dhanawas experience 143–152

Field-based research is the sine qua non for any technology programme to be undertaken in rural areas. Experience in rural energy programmes has clearly showed that the nature of the rural energy problem is extremely site-specific. Therefore, uniform, ready-made solutions are unlikely to be sustainable. Existing technologies (or new innovations) must be viewed in the light of requirements of the specific target community/population, modified accordingly, and then disseminated. Field-based research must essentially be a process of intensive back-and-forth interaction between designers of the technology and the final users. This requires a good deal of investment, in terms of finances and time and effort.

Specific learnings from Dhanawas

Fifteen years of field-based research in rural energy was of a great learning value to TERI. Though several of these lessons have been learnt and documented by other research institutions in the past, this experience further reinforces their importance. The main learnings are in the area of technology development as a major portion of TERI's work in Dhanawas was concentrated in this area. Some lessons can also be drawn in the areas of technology adoption process, delivery mechanism for rural energy technologies, and institutional aspects.

Before the specific learnings are presented, it is important to highlight the uniqueness of this experience. Rural energy planning in the country has largely focused on (1) household energy interventions such as improved cookstoves and biogas plants with multi-fold objectives and (2) energizing unelectrified villages (e.g. Urjagram, demonstration of photovoltaic technologies). The work in Dhanawas differs from other village-level experiments as it targets an electrified and economically developing village with strong links to urban centres.

In the context of replicating the work in Dhanawas, which represents many of the fast-growing rural areas in the country, TERI's work in this village has brought out certain possibilities that can be pursued at the national level by formulating appropriate policies and restructuring programmes.

The learnings are (1) rural energy research related, (2) related to planning, implementation, monitoring, and evaluation of rural and renewable energy programmes, and (3) technology specific.

Rural energy research

Clarity between research and development priorities

The Dhanawas experience indicates the need to distinguish between the research objectives and development objectives in a field-based energy programme. When TERI started working on reclaiming the degraded patch of land in Dhanawas, the villagers did not show any interest in the activity as they regarded it as a research project that could not be of any use to them at any point in time. In fact, this feeling of indifference continued for several years. It was only in 1989, when fodder from the plantation was used extensively by the villagers during a severe drought in the region that they began to see its potential benefits. However, it was only after several years when the improved soil quality gave it an economic value that the villagers truly began to take interest in the plantation. During the interim years, it proved extremely difficult to set in place any management system for the upkeep and maintenance of the plantation because of the sheer disinterest on the part of the villagers.

In retrospect, it may be argued that had some economic activity associated with the plantation been taken up right from the beginning, the village community might have taken some initiative to manage the plantation. Whatever may have been the outcome of such an initiative, it is amply clear that people are not likely to take interest in an activity unless it meets some of their demands or brings about an improvement in their quality of life in some way. While environmental benefits of research output may actually be beneficial to them in the long run, these alone are not likely to sell a technology or sustain a programme.

Sustaining technology development and research

One of the problems commonly faced in rural-based projects is the long gestation period between research work and the final accrual of the research output. This problem is especially difficult to contend with when the technology or device is being field tested, as the users are often impatient to see what benefits it can finally offer. The time duration in which the benefits of a technology will be received determines, to a great extent, the people's enthusiasm in a project. An energy programme that delivers benefits in a shorter time period is likely to be better and more easily received. The panchayat of Dhanawas could not see any immediate benefits flowing in from the plantation. They were, hence reluctant to participate in the project. For the success and sustainability of any technological intervention, there is a need to bring it to a threshold level till the people recognize the benefits it can offer. This may take a long time and the organization may need to invest a good deal of time and money into it. This was seen in the improved chulha programme in Dhanawas, where the Institute took considerable time to design the appropriate model of chulha and suitable delivery mechanism, which met the requirements of the people satisfactorily.

Energy research and the rural set-up

An important learning from the Dhanawas experience is that rural energy programmes cannot be undertaken in isolation to the village environment. In Dhanawas, the primary objective of setting up the VEDC was to keep the energy-related activities free from village politics. However, in spite of all the efforts, this could never be really achieved. The panchayat always played an important role in the planning and implementation of energy programmes.

Programme-related aspects

Integration of energy with other developmental needs

People in rural areas usually do not perceive energy shortages as a problem. When it comes to articulating their developmental needs and priorities, it is needs like employment opportunities, health care, and educational facilities in the village that take precedence over fuel shortages. This is in spite of the fact that women may actually be expending several hours everyday in the collection and processing of fuel, and making do with inferior quality fuels like roots, shrubs, and twigs. Hence, though energy shortages cause inconveniences, there are always more serious and impending problems to deal with. People are, therefore, not likely to adopt energy technologies or participate in programmes if these are not integrated with the other imminent developmental needs of the people.

Size and composition of the target group

A programme that benefits a large section of the population has more chances of being successful. This is especially true in case of community-owned services/interventions. At the time when energy plantation activity was initiated in Dhanawas, 71% households did not perceive any fuel problem throughout the year. The only section of the community that faced any kind of fuel shortages were the landless households, particularly the labour class, who neither had cattle nor could afford to buy commercial fuels. These, however, comprised only 13% of the total households. Consequently, enhanced fuel supply from the plantation was of interest only to this small group of families, which was the most deprived and least influential in the village. As a result, it was relatively easier for the panchayat to ignore the problems of this group and try to usurp the benefits of the plantation by felling the trees and use the land for agriculture, which generated income for the panchayat. This is not to suggest that only such technologies be introduced that benefit more number of people and the resource-rich sections of the society, but that in situations where the benefits accrue to a small section of people, adequate mechanisms must be set in place to ensure that the benefits do, in fact, reach them. It also requires a careful stakeholder analysis such that stakes of groups/individuals are identified and taken into cognisance while planning for the nature of benefits and their distribution.

Changing needs of the target population

It is essential to forecast the future of the programme as needs change with time and the general development of the region. For example, fuel scarcity could be a problem at a point in time due to shortage of biomass, which is further compounded by the poor availability of fossil fuels. However, over time, accessibility and low income may cease to act as barriers as linkages with the outside world develop and the village prospers. Long-term interventions need to be evaluated in terms of the relevance of the benefits in, say, 10 years and the percentage of village population that would ultimately benefit from it. For example, in Dhanawas, initially, the people showed a lot of interest in mud chulhas. However, in the early 1990s as more and more people started constructing pucca houses, the interest in mud chulhas waned and the villagers started looking for cooking devices that would last longer and were aesthetically superior to traditional mud stoves. As families moved from mud houses to cement and brick ones, the chulhas disseminated earlier were abandoned and demand for cement chulhas arose, rendering the Nada chulhas an obsolete intervention.

Creating maintenance systems

It is very important to ensure a strong and reliable maintenance back-up system especially during the demonstration phase of any technological intervention. When the technology is new and still in its trial phase, it is essential to ensure its smooth and trouble-free functioning. At this stage, the user is very unsure of the capability of the technology to deliver the expected benefits. Therefore, to maintain high confidence levels, quick and quality repair services are imperative. The biogas programme in Dhanawas was started as a demonstration activity in 1984 when TERI constructed the first biogas plant. The objective was both technology development and demonstration to determine the technical and socio-economic viability of the technology in the field. At that time, TERI staff was solely responsible for providing repair and maintenance services and were permanently stationed in the village. TERI personnel rectified all problems, however small in nature. The repair work included repairing the dome valve, cleaning the water trap valve, repairing gas chulhas and burners, cleaning the pipeline, etc. There were monthly visits to each plant to hear complaints and seek solutions. It thus involved considerable effort from TERI and commitment from the beneficiary in the initial stages of biogas development and implementation. However, with successive successful attempts, biogas soon became a household name.

The importance of an effective repair system cannot be overemphasized. This is true not only when technologies are in the demonstration phase, but also when they are fully mature and being disseminated on a large scale. In the villages of Jaisalmer, one of the reasons why people were willing to adopt solar lanterns was that a person from within the village was trained in the repair and maintenance and was responsible and accountable for all the systems.

Technology-related aspects

Suitability of the technology

For an energy technology to succeed, it should be suited to the needs of the people. It should blend well with the traditional lifestyles of the target population and not require major alterations in their practices. In Dhanawas, there was enormous potential to conserve biomass and provide a clean and cheap source of energy in the form of biogas to a majority of the households. About half the households in the village had enough cattle dung to have a family-size biogas plant. Of these 76% households belonged to the economically well-off category. However, a survey of these households showed that almost half of them were not willing to have a plant as they lacked sufficient space for construction. This was a ruling factor, particularly for the landless households. Further, lack of manpower for feeding and maintaining the plants, economic constraints, easy and adequate supply of crop residues as fuels, and resistance to adopt a new technology were some other reasons for not adopting the technology.

Likewise, an important consideration in the adoption of all the improved chulhas was 'convenience in making rotis'. The TARA chulha was unsuitable for roti-making in the traditional way. The Nada chulha was found suitable for cooking only in winters and monsoons, when cooking was done inside. On the other hand, in the 'Fuel substitution' project in Solan, it was seen that the villagers were willing to pay up to Rs 600 for improved cookstoves, which met all their needs for cooking and space and water heating.

It is also important to study the traditional technologies that people have developed for meeting a particular need. These may be preferred particularly if they are more cost-effective than the proposed new technology. The nocturnal water cooler was not well accepted in Dhanawas primarily because the traditional earthen pots were sufficient to meet the requirements of the household.

An analysis of the adoption process, response to, and performance of various technologies in Dhanawas clearly indicates the complex nature of the energy system in rural India. It is clear that any programme in the cooking energy sector should be preceded with an in-depth study of the various components of the system. For example, the introduction of improved cookstoves would require knowledge about parameters like the duration of cooking, place of cooking, commonly used fuels, and kinds of food cooked.

Continuous monitoring and evaluation

It is important to monitor technologies in their demonstration phase for a significant time period to establish their feasibility and work on possible modifications so as to harness the maximum potential available.

Ever since the first biogas plant was installed in Dhanawas, the performance of each plant was monitored closely by TERI staff. Continuous attempts were made to gain a thorough understanding of the variations in gas production under field operating conditions so as to maximize gas production while reducing the plant cost. Regular analysis of the monitoring data helped in identifying the problems with plant design and introducing necessary modifications. Modifications were made in the geometry of the digester, position of the inlet, and the scum-breaking net. Similarly, each time a new model of improved cookstove was introduced in Dhanawas, its performance was monitored carefully for a period of time. When Nada chulhas were introduced, they were monitored for their thermal performance, usage, and impact on cooking energy consumption. Other aspects evaluated included device preference, perception of advantages/disadvantages, reasons for installation, etc. An important finding was that a majority of the households interested in installing the improved chulha did not have a separate kitchen. Constructing the chulhas in the open was not feasible since these could get destroyed in rains. Further, the benefit of smoke removal, perceived as most valuable by a majority of the users, would not be received if the chulhas were installed outside. It was, therefore, decided to slow down the rate of dissemination of Nada chulhas till separate kitchens were constructed.

Coming to specific technologies, the experience gained in Dhanawas throws light on certain important factors related to the future potential of renewable and energy conserving technologies in rural areas.

Biogas

Biogas plants, meant to be replacements for traditional stoves to save wood and dung, have emerged as alternatives to LPG stoves. Their success in Dhanawas establishes their viability in a state that is known for its cattle population but not for biogas plants. The 100% functionality rate of biogas plants in Dhanawas indicates that biogas plants would be successful if the implementation is proper and a methodology is developed for providing post-installation services. TERI was able to design a user-friendly and a more rugged model. Now, most of the users carry out minor repairs themselves. This has helped to dispel doubts regarding servicing problems and has instilled confidence among the people.

The poor availability of masons for biogas plant construction and the time and effort needed in the construction of biogas plants with brick masonry suggests that a few more models based on prefabricated structures, ferrocement, etc., can be developed. Such a biogas plant, which can be installed and charged in a few days, will be more suited for rural entrepreneurs.

TERI is one of the premier institutes involved in developing a suitable model of biogas for rural areas. The R&D work done in Dhanawas has been a major input. The model (Mark IV-D) was researched and tested for an initial period in Dhanawas and then at different field sites. The Institute is now conducting a comparative analysis of performance of the model vis-à-vis the Deenbandhu model, which is approved under the NPBD. The objective is to get the TERI model approved by the MNES so that it can be widely disseminated under the NPBD.

Gasifier

In rural areas, where agricultural residue is one of the major sources of fuel, gasification based on briquetting appears to be a promising option. The gasifier system has emerged as an excellent option to utilize the agricultural residues efficiently. The system developed at TERI utilized agricultural residue in the form of briquettes. The green briquettes were found to be superior alternatives to dung cakes, especially in the hara, in terms of smoke emissions and efficiency. Subsequent experiments at TERI's Gual Pahari field station have shown that a gasifier can be operated in such a way that both gas and a large amount of char are produced, thus making the continuous production of briquettes possible. It may not be possible to leave the activity entirely to entrepreneurs, but it should be possible to develop entrepreneurs through this activity for future dissemination. In addition to producing briquettes, the gasifier system can be a suitable option for lighting and can retrofit diesel engines used for agricultural purposes.

Solar thermal technologies

Solar thermal technologies, in their present form, do not seem to be relevant to the rural areas. Hence, a concerted R&D effort to develop more appropriate technologies needs to be undertaken. This calls for a fresh look at the potential of solar technologies in rural areas. The technology menu could also be widened to include solar passive devices. TERI's experience with the SWH in Solan under the 'Fuel substitution' project has also demonstrated the possibility of such workable community systems. The use of solar cookers for community/ large-scale cooking (e.g. cooking done in the temple during religious functions), and the development of large-sized solar cookers for making dal, khichdi, etc., can be explored. Technology/device development, in the context of their application to rural end uses, should be treated as a dynamic process rather than a time-consuming process. The 'static' approach of installing 'available' devices without paying due attention to local conditions, resource availability, food habits, infrastructure available at the local level, etc., can only result in unsuccessful efforts.

Planning energy programmes and capacity building

Designing and conducting energy consumption surveys, assessing energy supplies, and estimating future demand were important components of the work done in Dhanawas. This helped in gaining a very rich experience in planning for energy needs. Experience in how to design surveys, what sort of information needs to be collected, how it is to be collected, analysed, and used for planning, etc., brought much understanding of the methodologies for decentralized energy planning in the rural areas. This helped the Institute undertake more energy planning exercises at the block/district level. In the following years, the Institute conducted several energy planning exercises for the MNES and various state governments. Within this, the Institute has also come up with a methodology for assessing biomass resources for power generation. In fact, TERI is now an apex body for coordinating such studies for the northern region of the country.

The Institute has also designed various training modules on orientation to rural energy and energy planning. It has published manuals on biogas construction for use by local masons, entrepreneurs, and NGOs. It has conducted several training programmes for both government officials and grass-roots level NGOs in line with the efforts at the national level to strengthen capacities to plan and implement renewable energy programmes.

Conclusion

The relevance of decentralized integrated rural energy planning is well established by the action-oriented research work done in Dhanawas and numerous other micro-level studies/ projects done within and outside TERI. As issues in rural energy are local, they need to be dealt with in the context of the local situation. Thus, what remains central is the need to consider the sociocultural diversity when planning and implementing energy strategies. In fact, such strategies need to emerge from the people. Hence, the involvement of village communities is critical.

The government programmes on rural and renewable energy, however, continue to be target driven. As more emphasis is laid on meeting the assigned targets within the financial year, no effort is made to consider the ground realities. The sociocultural and political context within which technologies and programmes are accepted or rejected is only glanced over. Since their inception national programmes such as the NPBD or the NPIC, which are essentially rural-based, have been planned and implemented in the same manner. Targets are set from the top and then assigned to several agencies implementing these programmes at the grass-roots level. The innovative approaches to implementation and planning, whether in rural renewable energy programmes or other development programmes, have also not been used to draw lessons at the national level. It is these local initiatives and experiences which need to drive policies and programmes in the future.

As mentioned earlier, to make any energy programme sustainable, it is imperative that the priorities of local people are addressed and that they are actively involved in the management of the system. In this context, more attention needs to be paid to developing income-generating activities where energy is a key input such as flour milling, oil expelling, crop drying, and mushroom cultivation. Such village-level industrial development can be a major focus of energy programmes. In many of these activities, devices such as the gasifier and the solar air heater can be gainfully employed. It is highly desirable to train rural entrepreneurs and involve them in income-generating activities related to energy development. Experiences with the VEDC suggest that alternative institutional models need to be developed to manage community resources.

Rural energy is emerging as a global phenomenon. There is thus a need for establishing national/international networks for information sharing. Working with people should be the dominant theme. There is a need to pay more attention to the role and potential of local organizations in programme planning and management. A shared understanding of the local situation is, therefore, required. There is also a need to design mechanisms that will facilitate the feedback from village-level rural energy programmes to the policy makers. Ways of structuring the learning process gained from field experiments, testing in pilot projects, and adaptation through demonstration must be identified prior to disseminating these to a wider audience of policy makers, planners, and extension field staff. There is thus a need for increased documentation and reporting. Non-governmental organizations should also be recognized as equal partners in planning and implementation as they are often the teachers and sources of inspiration for learning how to work better with villagers.

Field experiments and pilot projects are valuable learning opportunities. However, the rapid changes in rural areas require this learning to be a continuing process. A willingness and preparedness to learn from those who know their system most intimately – the people – is definitely required.

Chapter 13

Directions for the future

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Background

The importance of the energy sector was recognized as early as the First Five-Year Plan (1951–56), which prioritized agricultural development including irrigation and power. The first broad study of trends in energy demand and supply in the country was undertaken in 1963–65 by the Energy Survey of India Committee, appointed by the Ministry of Irrigation and Power. At the same time, a unit concerned solely with energy problems was established within the Planning Commission.

The problem of energy supply to rural areas was taken up in 1974 by the Fuel Policy Committee, which examined in detail the issue of inter-fuel substitution after the steep rise in the price of oil in October 1973. The committee pointed out that the quantity of non-commercial fuels used would decrease gradually from the Sixth Five-Year Plan (1980–85) after having reached a peak. The committee, however, also stated that the magnitude of firewood used would continue to be so large compared to the availability of the resources that there were likely to be serious repercussions with regard to the conservation of forests and the consequential ecological problems (GoI 1974). Highlighting the contribution of gobar gas plants to other social benefits such as nutrient production and pollution abatement, the committee called for further popularization of the technology even though their contribution (quantitative) to meet the fuel needs of the domestic sector would probably be limited (GoI 1974).

In view of the dwindling supply of conventional energy sources and the resulting rise in the real price of energy, the Working Group on Energy Policy (1979) in its report stressed on an increased reliance on renewable sources of energy in (GoI 1979). The report also stressed that R&D effort in the fields of solar energy and biomass should be accorded high priority considering their vast potential and their relevance to rural energy programmes. On its part, the Sixth Plan recommended decentralized energy production for meeting the energy requirements of the rural population. The plan document emphasized that 'the optimal mix of energy supply technologies for each location would have to be individually evaluated'. It went on to state that, 'One of the schemes of the Sixth Plan is to set up a number of such integrated energy systems on a pilot basis so as to get a feedback not only on the technological aspects but also on the institutional arrangements for operating such systems and the associated socio-administrative problems' (GoI 1981). In 1981, CASE was set up to formulate policies and programmes for the development of NRSE, coordinating and intensifying R&D activities in NRSE, and ensuring the implementation of government policies in regard to all matters concerning NRSE. A year later, the DNES was created in the Ministry of Energy. The role of NGOs was highlighted when in 1984 the Advisory Board on Energy recommended intensification of the afforestation programme on all types of land, particularly degraded and wastelands of government departments and local bodies, with the help of voluntary agencies, educational institutions, and local bodies. The Board also recommended demand-side management to meet domestic energy requirements (GoI 1984).

Ten years after the formation of the DNES, it was upgraded to the level of a ministry. The activities of the MNES are being carried out under six broad groups, namely Rural Energy, Solar Energy, Power from Renewables, Energy from Renewables, New Technologies, and Administration and Coordination (MNES 1998).

Several programmes and projects have been implemented in the rural energy sector with focus on technology dissemination, research, and development. The attempt has been to conserve energy and provide alternative energy options through appropriate technologies. Rural areas have been a primary focus of these projects/programmes, which include the NPBD, NPIC, Biomass Gasifier Demonstration Programme, and Solar Photovoltaic Demonstration and Utilisation Programme. Of these, the NPBD and the NPIC are the largest in terms of investment and coverage, respectively.

Despite all these initiatives at the policy and programme level, the use of non-commercial energy sources continues unabated. The Seventh Plan (1985–90) document states that a little less than half the energy used in the country comes from cow dung, fuelwood, and agricultural wastes. It, therefore, stresses on the urgency of addressing the energy crisis in the rural areas due to the indiscriminate use of non-commercial energy sources (GoI 1985).

Some of the rural renewable energy programmes and the problems being faced in planning and implementation are discussed in the following sections. Areas of emphasis requiring policy review and programme restructuring have been brought forth from these discussions. TERI's experience, especially at the grass-roots level, has been heavily drawn upon to highlight some of the issues. No solutions have been prescribed for this would require considerable debate and discussion at the national level. However, the attempt has been to bring forth priority issues, which need reflection of the government, the industry, research and academic organizations, NGOs, and other players in the rural and renewable energy sector.

National programmes on biogas and improved chulhas

National Project on Biogas Development

The NPBD was launched in 1981/82 to promote family-type (2 cubic metre) biogas plants in the rural areas of the country. The stated objectives of this programme are providing fuel to rural households for cooking and organic manure for application in agricultural fields, thereby mitigating the drudgery of rural women, reducing the pressure on forests, and recycling human wastes by linking toilets with biogas plants which in turn would improve sanitation (MNES 1998). Under the projects, 2.71 million family-type plants have been installed, covering only one-fifth of the total estimated potential of 12 million plants (MNES 1998). The functionality rates reported are low (66% [NCAER 1992]). Structural defects (damages in foundation, cracks in dome and digester wall, etc.) and technical operational problems (corrosion/leakage and water accumulation in pipeline, defect in burner, etc.) are reported to be the main reasons for plant failures (NCAER 1993).

National Programme on Improved Chulhas

The NPIC was launched in 1985 with the stated objectives of (1) conserving fuelwood, thereby checking deforestation, (2) eliminating smoke from kitchens, (3) reducing the drudgery of women and girl children, and (4) generating employment in rural areas (MNES 1998). Over 28.5 million improved chulhas have been promoted. The NPIC had foreseen an estimated potential of covering about 120 million rural and semi-urban households (MNES 1998). A survey conducted by the NCAER at the behest of the MNES found that 71.8% of the stoves installed during the previous three years were functional (NCAER 1993).

Issues

At the current rate of dissemination and level of functionality, it will be difficult to realize the total potential of biogas and improved chulhas in the near future. Even in areas where they have been installed, the technologies have not benefited the local communities in a wholesome manner. Apart from basic technological constraints, there are several programme areas that can be strengthened to achieve a better performance.

Beneficiary selection

Households without adequate livestock or water to run the plant have been selected for biogas installation. At times, target groups are not short of fuelwood or do not perceive any shortages. Hence, when improved cookstoves are promoted as fuel-saving devices, they find few takers. The improved cookstove programme will, therefore, be more relevant to areas where there is a perceived scarcity of fuelwood, for example, in arid regions where trees grow very slowly. In other cases, in villages like Dhanawas, where fuelwood scarcity was not perceived, promotion of improved chulhas was done highlighting the smoke-removal benefit. In other words, user needs and the changes desired in the traditional system have to be studied thoroughly before disseminating biogas or improved cookstoves. A detailed assessment of user priorities before fixing targets is essential and has to be made an integral part of the ongoing programmes on rural energy.

Low confidence levels

For the biogas programme, the large number of dysfunctional plants has led to low confidence levels among both users and non-users regarding the feasibility of the technology. The NCAER survey identified defects or damages in the foundation, digester, and fixed dome, which are the most vulnerable parts in a plant, as the main reasons for non-functionality. The scattered distribution of plants and inadequate training of the users in the maintenance of their plants have also contributed to low functionality. It would thus be useful to adopt a cluster approach for the installation of plants along with rigorous user education and training. It was much easier for TERI to create/provide back-up services for repair and maintenance of biogas plants in the three cluster villages in Sultanpur district, namely Lakhnipur, Mohammadpur, and Uttargaon. This was because village clusters were selected so that post follow-up would be easier (TERI 1998). Other NGOs are also following a cluster approach, but the strategy needs to be promoted more vigorously. At the policy level, there is also a need to promote the turnkey approach in a more focused manner to implement the biogas programme through village-level entrepreneurs. Training local technicians and signing annual maintenance contracts with the manufacturers in the case of solar devices created a back-up service that ensured that the devices remained in good working order (TERI 1998). This strategy will also help in generating employment in rural areas while providing maintenance and repair support to installed devices.

Design-related problems

There are also problems with the existing models of biogas plants being disseminated under the NPBD. As stated earlier, structural defects and operational problems have resulted in many failures. This has happened mainly due to lack of efforts under the programme to improve the Deenbandhu model. TERI closely followed the progress of the biogas plants (the TERI model) installed in Dhanawas, monitored data collected continuously, and recorded user feedback. The data were then used to improve the plant design. TERI has thus been able to design a more rugged model, which has minimized failures due to structural defects. Operational problems have been reduced through user training, which was organized in a systematic manner involving both men and women of Dhanawas. Above all, the introduction of features such as better utilization of gas and preventing scum formation in the design minimized the services required after construction.

Field experiences have shown that durability is also an important criterion for adoption of improved cookstoves. A metal cookstove, if properly maintained, will last for about 18 months. A mud stove will last for an even lesser time. Hence, there is a need to focus on stove designs that last longer such as cast iron stoves.

Narrow research focus

The other serious drawback of the biogas programme has been its sole reliance on animal dung. Research work funded by the MNES on the development of alternative feedstock has so far been only in the form of laboratory experiments with few demonstration projects. Research is not being conducted on current problems faced such as low gas production in cold climates and lack of water.

Under the NPIC, the focus of the improvements carried out has been only on the cookstove. Considering the large variety of cookstoves in use, the type of biomass consumed, food habits, and cooking practices, it is an extremely difficult task to achieve the objectives of efficiency improvement and smoke removal (Kishore 1997). It becomes even more difficult to do so if the focus is only on improvements in the device – the cookstove. There is a need to look at the entire cooking energy system – stove, pots, utensils, food cooked, the kitchen, fuel, and the cook – for achieving the goals of efficiency and smoke removal. Further, user priorities, which may be other than fuel saving and smoke removal, such as convenience, aesthetic appeal, and durability should also be addressed while developing stoves.

Lack of adequate training

Like in the case of the biogas programme, lack of adequate training in chulha construction has led to low functionality. Chulhas, whether metal or mud, have a relatively short life (1–1.5 years, typically). If the users (women) are not adequately trained in chulha construction, they either abandon the chulhas once they get damaged and revert to using the traditional chulhas or modify the stove dimensions while repairing it such that the increased efficiencies are no longer obtained. Thus, if the improved chulha programme has to make an impact in the long run, women have to be convinced of its superiority and trained adequately in construction and repairs.

Summing up, there are certain areas that need to be strengthened in the planning and implementation of household energy programmes. These are

1. training and capacity building at all levels
2. repair and maintenance support
3. local entrepreneurship
4. sensitivity among the implementing agencies towards users needs and perceptions.

There is also a need to review the overall approach to planning and implementing the NPIC and the NPBD. The centralized, target-based, subsidized approach in which these programmes are controlled and managed by the MNES has influenced their performance considerably. The rationale for fixing targets is based on past performance, which is assessed in terms of the targets achieved. This emphasis on 'numbers' does not reflect user requirements. In a hurry to achieve the allotted targets, aspects such as awareness generation, training, and maintenance are often neglected. There is, hence, a need to ensure that the targets flow from bottom to top. Since technologies such as biogas have potential only in specific areas, there is a need to identify such areas (e.g. agriculturally prosperous, with adequate livestock) for dissemination. Besides identifying potential geographical areas, target groups should also be identified and location-specific strategies need to be developed. If the insufficient number of cattle owned by families is the principal barrier to promoting biogas, then providing a soft-loan package that covers both the biogas plant and purchase of one or two heads of cattle can be tried (Ramana 1998).

The other important issue is that of direct subsidies. Unlike what was envisaged and is still claimed under the programme, subsidies have not benefited the poor families. The objective of making biogas accessible to poor families has not been achieved. They still have insufficient cattle and space. Instead, it is the well-to-do families, who could have afforded to get a plant constructed even otherwise, that have largely availed of the subsidies (Ramana 1998). There is hence a need to review the policy on subsidization of biogas and improved chulhas. Perhaps they are better directed to other aspects of the programme that need strengthening such as awareness creation, training, and R&D.

Biomass briquetting

Use of crop residues has several problems associated with it. Agricultural residues have poor combustion properties due to their low bulk density. Their relatively smaller particle size (e.g. straw) makes them burn too fast, making it difficult to obtain a satisfactory level of heat for cooking. These problems, however, can be largely overcome by compacting the loose biomass (compression ratio of approximately 7:1) to form briquettes. Though the use of biomass briquettes for industrial use is well established, its penetration as a cooking fuel in rural areas is slow. The central government provides financial assistance in the form of interest subsidy to biomass briquetting units. However, the scale of promotion is limited. Experience shows that the development of satisfactory technologies is not sufficient to ensure their adoption. The product has to match the availability of local raw materials, the traditional cooking devices, cooking practices, dietary habits, etc. Further, the high pressure applied in the manufacturing processes makes it unlikely that briquettes with such low densities can be produced so as to fit in existing stoves. The best that can be achieved is the use of briquettes to refuel a fire after it has been started on wood and charcoal (McChesney 1985).

On the other hand, the use of briquettes in the hara promises large scope in terms of savings in use of dung cakes as fuel. The demonstration experiment in Dhanawas showed that animal dung can be better utilized as a binder in briquette making than as the sole fuel in the hara. Simple technologies, screw press and sun drying, were applied successfully for producing briquettes from local resources at low cost. Later experiments showed that the quantity of dung cakes consumed for the same task in the hara was nearly 2.5 times greater than (by weight) either char or mustard straw briquettes and the same task could be performed in nearly half the time when using briquettes (Malhotra et al. 1997).

Another argument in favour of briquetting biomass for use in the hara is that though more efficient stoves/devices could reduce residue consumption, these would have to be designed for specific residues and operated properly to achieve the savings and the desired benefits. The low rate of dissemination of stoves and the time required to design or modify the traditional devices make it difficult to achieve an immediate impact on residue consumption. Hence, upgrading the residues to the level of wood fuel substitutes by means of a briquetting process and using these in the traditional devices such as the hara seem to be a more appropriate solution.

Regarding the availability of raw material, domestic fuel usage itself provides an enormous source for briquetting. There is high availability of crop residues in states that use the hara, which can be utilized for briquetting. Their share in the total production of crop residues is: Bihar 6.7%, Haryana 4.4%, Madhya Pradesh 7.5%, Punjab 10.4%, Rajasthan 4.1%, and Uttar Pradesh 16% (TIFAC 1992). According to NCAER estimates, these states are the highest consumers of dung cakes. In fact, the per capita daily consumption of dung cakes as fuel is higher than firewood for a majority of these states (TERI 1992). A research and dissemination programme can hence be launched for exploring possibilities of using biomass briquettes in the hara.

Solar cookers

In 1982, the government introduced solar cookers as a cost-sharing scheme, wherein a government subsidy was given on the device. In 1994, the subsidy on solar cookers was withdrawn and these began to be promoted on a demand-driven basis. For this, grants-in-aid are provided to nodal agencies for publicity, promotional incentives, establishment of sales outlets (with necessary repairs and maintenance facility), and organization of cooking competitions, training, and demonstration programmes. A total of 462 000 solar cookers has been sold in the country from more than 500 district offices of state agencies and private dealers (MNES 1998).

There are, however, some problems being faced in the promotion of solar cookers. Besides some inherent problems in the technology itself, there are very few entrepreneurs in the field for production. Other barriers to the promotion of solar cookers include the traditional use of biofuels, large family size, incompatible cooking and meal times, and varied diet habits. In view of these barriers, considerable R&D will be required in the future. Further, as part of the promotional strategy, a sustained awareness campaign in small areas will be more effective rather than dissemination on a large scale.

Keeping in mind the rural consumers, application of solar cooker for cooking fodder will be more appealing. As far as entrepreneurship development is concerned, some possible initiatives are described below.

Product development

The solar cooker should be developed as a more user-friendly device. Entrepreneurs or manufacturers can be involved in this endeavour. However, the present manufacturers operate at a very small level and have no capacity for carrying out any in-house R&D. Thus, there is a strong need to support manufacturers to carry out R&D. The focus of R&D should be on (1) making the usage of the device more flexible in terms of the amount of food that can be cooked and choice of vessels, and (2) making it more aesthetically appealing.

Identifying the market

Since the solar cooker is not a complete cooking system and only supplements the existing system by saving fuel, the relevant markets are households using commercial fuels for cooking. The most attractive market segment for solar cookers would be households using commercial fuels willing to pay a premium of about Rs 1000 to decrease the inconvenience of uncertainty in the availability of the preferred fuel (LPG). A much larger number of such households are likely to be found in peri-urban and urban areas.

Marketing infrastructure

The commercial success of any product demands visibility in the market and ease of availability. Higher penetration of solar cooker requires an increase in the number of retail outlets. One possible outlet could be the LPG dealers. The purchase of solar cookers off the shelf, a recent phenomenon, needs to be promoted further.

In short, the successful promotion of solar cookers in rural areas requires several modifications in the product design. In its present form, it is unsuitable for rural cooking applications, especially at the household level. The creation of infrastructure for marketing solar cookers in rural areas can be initiated only after considerable investments have been made in R&D.

Biomass Gasifier Demonstration Programme

The MNES initiated a programme on biomass gasification technology and its utilization in 1984/85. The Biomass Gasifier Demonstration Programme was modified in 1993/94 with focus on the adoption of a market-oriented approach for the promotion of gasifiers for thermal, mechanical, and electrical applications. During the period 1994/95 to 1997/98, 220 biomass gasifiers with an aggregate capacity of 17.7 MW were set up for thermal and electrical applications (MNES

1998). To promote the use of gasifiers for village electrification, financial assistance is provided for preparing the detailed project report, project cost to state nodal agencies, private entrepreneurs, etc.

Despite its high relevance in rural areas, where the availability of electricity is poor and efficiency of biomass utilization low, the focus of the programme has so far been on applications in the industrial and commercial sectors. The Dhanawas experience has shown that a decentralized gasification system can be successfully set up for power generation. System sizing for meeting such loads also indicates that for electricity generation at the village level it is not normally possible to have a gasifier of too small or large a capacity. A suitable load would be about 20–30 kW. A multi-purpose gasifier that could use both firewood and briquettes made of crop residues and animal dung would be most appropriate.

In the long run, gasifiers can be a more cost-effective investment for power generation to meet domestic loads in rural areas than other renewable energy technologies such as photovoltaics. While gasifiers can be upscaled to meet future demand without much investment, photovoltaics will be very expensive. The quality of power supply by gasifiers will also be superior. It has been estimated that, using the same quantity of biomass, it is possible to meet the cooking energy requirements and generate electricity by adopting gasification technology in an integrated manner (Kishore 1994). Hence, there is a need to set up stand-alone integrated gasification systems at the village level. Institutional arrangements such as entrepreneurship development, collection of biomass, and tariff setting can also be worked out as part of the project proposal. Ideally, programmes such as wasteland development through afforestation and power generation through gasification can be made parallel programmes.

Solar Photovoltaic Demonstration and Utilisation Programme

The MNES has been implementing a programme on the demonstration and utilization of SPV systems for various applications. The systems being deployed under the programme include solar lanterns, home lighting systems, street lighting systems, and small capacity village-level power plants. The implementing agencies at the state level are the state renewable development agencies and select NGOs having MNES recognized 'ADITYA' solar shops. Of the aggregate capacity of 39 MW (500 000 systems), the maximum deployment is in the telecom sector (36.3%), followed by exports (10.0%), pumps (7.5%), home light (7.0%), street light (5.5%), power plant (5.0%), and lanterns (4.5%) (MNES

1998). No national-level figures are available regarding the performance of these systems. Independent studies emphasize the need for strong maintenance and back-up services for successful performance of the systems (Maithel et al. 1997).

There are several inherent problems in the dissemination of the products and in the strategy adopted for their dissemination. The approved designs under the programme stifle any innovations. The designs have been prescribed with the sole objective of providing minimum lighting to rural households, without adequately addressing the user needs. This inhibits the development of an active market for these products. The central subsidy, on the other hand, is given on the design rather than on providing maintenance and follow-up services, training, etc. Since the installations are scattered, provision of repair and maintenance is difficult. Grass-roots experience with SPV installation shows that a cluster approach makes follow-up much easier (TERI 1998). Local technicians can be identified and their existing skills can be built upon to repair solar devices. A working capital loan needs to be provided to the trained individuals mainly to take care of costs of specific repair instruments that may be required. At the policy level, there is also a need to identify who will take the onus of creating the infrastructure – physical and financial – for support and maintenance. The key players here are the MNES, IREDA, and the industry, that is the manufacturers of PV systems. Thus there is an urgent need for a policy dialogue on this issue.

Another issue of concern is that the demonstration programme runs parallel with the IREDA–World Bank programme, which is commercial in nature. The MNES permits direct marketing of the SPV systems by the manufacturers under the demonstration programme. On the other hand, it encourages state agencies and NGOs to avail of soft loans from IREDA for SPV systems under the IREDA–World Bank programme (MNES 1998). This creates ambiguity in the roles of various stakeholders. Such a duality may not be good for the SPV programme as a whole.

The subsidies that continue to push SPV technologies in the rural areas are also a cause for concern. The rationale for subsidy may be to provide the initial push to technologies or to meet the 'welfare' objective of rural development programmes. The key issue is for how long can the technologies be demonstrated and subsidies provided. The SPV programme focuses on providing minimum lighting to households in remote and inaccessible villages where it is difficult or too costly for the grid to reach. However, it took over a decade to identify the high focus areas for giving a thrust and ensuring visibility to the programme. Keeping to the initial focus of the programme, it would be more appropriate to target subsidies to such high focus areas instead of dispersing them over the entire country. This is required since subsidies also mean a heavy drain on the country's financial resources especially as the scale of operation increases.

SPV Water Pumping Programme

The SPV Water Pumping Programme was started in 1993/94 for promoting SPV water pumping systems for agriculture and related uses. The objectives of the programme are the gradual introduction of SPV water pumping systems, development of marketing infrastructure for these systems, and collection of direct feedback on the performance and utilization of the systems for meeting the specific needs of the users in different agro-climatic conditions for different categories of users and various end uses (MNES 1998). IREDA has been entrusted with the implementation of the programme. The programme is further being implemented by the various state nodal agencies. A combination of subsidy (at Rs 125 per peak watt of PV array, maximum of Rs 200 000 per system) and soft loan (at 5% for the unsubsidized part of the price of the pumping system subject to a maximum of Rs 250 000) is provided to the user for water pumping systems in the range of 200 – 2250 W PV array capacity. A cumulative total of 2787 SPV water pumping systems had been installed by 31 December 1998 (MNES 1998).

The central issue in the case of pumping is that PV systems are very expensive compared to conventional options like diesel pumps even if the hidden latent costs are considered (Kishore 1997). Further, community-level systems would require strong institutional support to manage and operate as was experienced by TERI in both Dhanawas (Haryana) and Lakhnipur (Uttar Pradesh), where SPV water pumps were installed for drinking water. This would require considerable investments in building and strengthening local institutions. These aspects are, however, missing in the national programme.

Renewable energy programmes: key issues

A study of the rural and renewable energy sector indicates some important issues that require urgent policy review. These issues relate to R&D, programme planning and implementation, and capacity building.

It is important that R&D is made an integral part of rural and renewable energy programmes. As of now, this is not happening. The design specifications and accessories of the

Deenbandhu biogas plant, for instance, has remained the same since the late 1980s when the model was approved by the MNES for large-scale dissemination under the NPBD. The system size in the case of PV systems is fixed providing no scope to design the wattage according to user requirements.

Perhaps, the main lacuna in the ongoing programmes is the lack of an assessment of the social structure, roles, and status that determine the relationships among individuals, groups, and communities in a rural social set-up. The influence of social and political factors such as caste, gender, kinship, income, leadership, land holding, and their bearing on the programme are not assessed and planned for. These factors are even more important in close-knit rural communities. Working with rural people requires a knowledge and understanding of the dynamics that determine village actions and decisions. On the other hand, strengthening institutional mechanisms at the grass-roots level for managing programmes is totally neglected. As of now, the programmes are entirely managed and planned by the MNES, leaving the organizations at the grass-roots level (government and some non-government) to chase targets and get money for the next financial year. As a result, concepts such as that of 'turnkey worker', though novel, lack accountability in the absence of any village-level institution regularly monitoring the work done.

A single body is, therefore, essential at the village level for planning, implementing, and managing energy programmes. This single body should, however, be an enterprising unit, that is, the people should pay for the services offered by the body. TERI was a facilitator and a member of such a body in Dhanawas along with the local people. However, it could not continue to remain so forever. Further, the role performed by the villagers and key persons had to be formalized/internalized. The creation of the VEDC was an attempt to hand over the activities of planning and management to a village-level institution. Training local masons in biogas construction, local technicians in maintenance of solar lanterns and SPV pump, village men and women in nursery raising and management, etc., was carried out to create a pool of skilled manpower to implement and manage different technologies. Local people were involved in carrying out energy surveys, conducting technical experiments, and preparing implementation plans thereby developing their skills in programme planning. Finances were managed jointly with the VEDC. On the other hand, households had to pay for the services offered – household contributions were collected for extending water distribution pipelines from the solar pump and the households paid the trained local women for repairing their chulhas.

In the 'single window' approach, all services – technical, financial, repair, and maintenance – should therefore be provided to the user. Strong organizational support, such as that provided by TERI, is necessary to give technical inputs and provide training. Typically, an 'energy service unit' can be created for a village or a cluster of villages comprising local leaders, technicians, financing agencies, NGOs, and research institutions to plan, implement, train, finance, and provide technical inputs and maintenance services, thus functioning as a local enterprise.

Another significant aspect, which has not got due attention, is the monitoring and evaluation of programmes for introducing continuous improvements – technical, financial, and institutional. Unfortunately, in the ongoing programmes monitoring is being done to fix annual targets. Using the monitoring data to adapt the technology to suit local requirements is necessary such that the project/programme evolves instead of remaining static. By continuously monitoring the installed devices in Solan, TERI was able to develop an improved chulha based on a careful study of local designs and user requirements and in Jaisalmer, bring improvements in the design of solar lanterns. The evolution of the TERI model through research work in Dhanawas and further work in Uttar Pradesh and Tamil Nadu has brought it to a stage where it is now being field tested in comparison to popular models such as Deenbandhu and VINCAP so as to seek approval for dissemination under the national programme.

Conclusion

A majority of the renewable and rural energy programmes in India follow the centralized target-oriented approach with little reflection on the requirements of the people. Such an approach has greatly influenced the performance of the programmes. Most programmes are spread too thin as a result of which they have made little impact on the overall rural energy scenario nor have they brought about significant improvements in the quality of life of the rural people. Subsidies continue to push technologies which are being 'demonstrated' even after a decade of dissemination. Support for R&D continues to be in the form of short-term low-budget projects to research and academic organizations without envisaging specific outputs or examining their relevance in the future. There is very little field to laboratory transfer of feedback resulting in no new models/designs, or improvements in existing models/designs. The 'welfare' and 'market' objectives are running parallel to one another, inhibiting the market forces to come to play in case of PV technologies. As the PV industry is mainly dealing with the captive market of government and institutions, they have no incentive to develop products and reduce costs. On the other hand, since the industry has little interaction with the rural consumer, the field performance goes unutilized in driving further R&D.

The fact remains that as long as conventional sources of energy continue to be heavily subsidized, renewable energy sources are unlikely to make any dent in the rural energy scenario. On the other hand, the centralized target-based subsidy-driven national rural and renewable energy programmes have led to a total neglect of aspects of awareness creation, need assessment, follow-up, and capacity building, which are key to programme sustainability. It is thus important to review target allocation and the subsidy policy. Increased role for NGOs and village institutions in the rural and renewable energy sector should be assessed and formalized.

Ensuring the equitable distribution of benefits of programmes would go a long way in bringing about an overall improvement in the quality of life of rural people. Grass-roots experience with energy programmes has shown that benefits continue to be usurped by the economically strong and influential sections of the rural society. A sensitivity to the power play, which may be governed by caste, clan, gender or income is essential. Increased involvement of NGOs will help in designing programmes that are closer to the social and cultural realities of rural society.

In the future, as changes occur in the rural economy, lifestyles, and aspirations of the rural people, the energy needs and consumption patterns are bound to change. Demand for energy is likely to increase, making efficient energy utilization even more important. There is hence an urgency to tailor national programmes to meet future demands in a sustainable manner.

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Annexure 1 TERI fixed-dome biogas plant

Rural energy matters: the Dhanawas experience 171-179

The R&D work in Dhanawas contributed significantly to the development of the TERI model biogas plant. Between 1985 and 1997, as many as eight different prototypes were constructed and tested in Dhanawas. Some of the main features of the R&D on the TERI model biogas plant were as follows (Kishore et al. 1998).

- No external funding was available and all the work was carried out with internal funding only. Hence no special project staff were employed.
- No infrastructure was available to carry out laboratory work or controlled experiments on pilot-scale models. Hence all the experimentation, data collection, etc., was done on plants used by the owners.
- For trying out new models/devices/add-ons to the plant, an assurance was given to the user that the plant will be rebuilt or rectified at TERI's cost if the performance was not satisfactory.
- A cost-sharing arrangement was made with the users wherein TERI provided services, supervision charges, and some labour freely and the owner procured all the materials.
- Data collection at the field level for gas production, dung input, etc., could not be done in a systematic and controlled manner due to both logistical problems and inadequate manpower.

Background

TERI began research on biogas in the early 1980s at its field research centre in Pondicherry. In the initial stages, the focus was on modifications in the existing Janata model to reduce the structural failures. In early 1985, the Institute installed and operated a 10-cubic-metre/day biogas plant at a T B. Sanatorium in Varvala, near Mithapur, Gujarat. Here, coal was used as the main cooking fuel, which was purchased at the rate of Rs 2/kg. Dung was obtained from the 25 cattle supplying milk to the sanatorium. The objective of constructing this plant was to reduce the expenditure on fuel (coal) and to effectively utilize the available dung. The plant (Mark I model) was built using poor quality bricks. This was mainly because the recommended first-class bricks were not available within a distance of 100 km of the site. Additionally, the recommended river sand for preparing cement mortar was not available. The only sand available was sea sand, which is not recommended because the salt in it could weaken the structure. To counter this, sea sand from a slightly higher terrain, which did not contain any salt, was used. The following precautions were taken to cope with the problem of poor quality bricks.

- The bricks were soaked in dilute cement water solution before use.
- A higher proportion of cement than normal was used in the mortar for the construction of dome and walls.
- The quantity of mortar applied for construction in the entire gas space was higher than normal.
- A chicken wire mesh reinforcement was provided outside the dome.

The salient features of construction were

- a 100-mm-thick bottom concrete with steel reinforcement
- a brick dome with a perfect spherical shape constructed with the bamboo-nail support method
- additional reinforcement of tiles over the brick dome
- thorough and careful plastering of all gas space inside the plant.

This ensured that the digester is able to withstand a pressure of 100-cm water gauge.

A shallow solar pond was provided with the plant so that hot water could be used to increase gas production in winters. Biogas production rate was monitored for three years and the average gas production was found to be 7.9 cubic metres/day. The system worked well and reduced the use of coal by 39% and that of dung cakes by 40%.

Biogas development: the initial efforts in Dhanawas

During the early years, R&D in biogas was directed at perfecting the technique of dome construction and increasing gas production in winters. The main focus of R&D activities in Dhanawas was on (1) improving the functionality and reliability of the plant, (2) reducing the initial cost and installation time, and (3) increasing the gas production rate. The first plant in Dhanawas was constructed in 1985. This 2-cubic-metre capacity plant was similar to the Janata model (cylindrical shape) except that a stirrer had been provided (Mark II). The second 2-cubic-metre biogas plant (Mark III) was constructed in 1986, which, unlike the previous plant, had a flat bottom. In this plant, the gas production fell considerably during winters. Analysis suggested that the digester temperature could be increased by mixing cow dung with hot water instead of cold water before feeding it into the digester. To increase gas production during winters, a shallow solar pond was also provided to supply hot water for slurry mixing. The plant owner was instructed to use the hot water for making cow dung slurry to feed the plant. The shallow solar pond gave 50 litres of hot water in a day at 50 °C, which was enough to meet the daily water requirements of a 2-cubic-metre biogas plant. However, the family members preferred to use the hot water for other purposes such as bathing and washing utensils. As a result, the digester could not be kept warm in winter and the shallow solar pond was subsequently removed. The digester temperatures and gas production rates for the 2-cubic-metre plant are shown in Figure 1. Stirring and scum-breaking devices were also tried out and a nylon net placed in the slurry movement zone seemed to give a better gas production rate (Mark III). The earlier models (Mark I–III) had an HRT (hydraulic retention time) of 50 days.

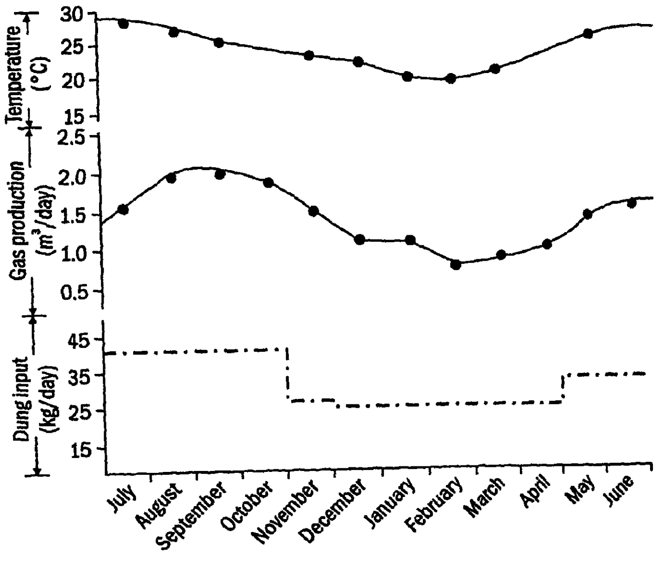

Figure 1 Performance of biogas plant (monthly average values of digester temperature, daily gas production, and dung input)

Development of the spherical model

In 1984, AFPRO (Action for Food Production) started work on the now popularly known Deenbandhu model. The model was approved for dissemination by the Government of India in July 1986. The Deenbandhu model was considered the most significant development in India's biogas programme as it reduced the cost of the plant to almost half that of the earlier KVIC model. The cost reduction was achieved by minimizing the surface area by joining the segments of two spheres of different diameters at their bases. This structure, therefore, acted as a digester as well as a gas storage unit. This also gave the model structural stability. A completely spherical model, known as the football model, was also built around this time in Gujarat, which was, however, not well publicized.

TERI constructed its first spherical model (Mark IV-A) with an HRT of 40 days in November 1986 in Dhanawas. Regular monitoring of the plant showed that the gas production figures for Mark IV-A (0.31 m^3/m^3.day) were consistently lower than that of the Deenbandhu model (0.41 m^3/m^3.day). However, such comparisons could not be taken as an index of performance for the following reasons.

1 The two plants were located at different sites.
2 The data for the Deenbandhu plant were obtained under controlled laboratory conditions, while that for the Mark IV-A model was in actual field conditions with varying dung inputs.
3 The Mark IV-A model was the first plant of its type to be constructed, while Deenbandhu was fairly standardized when the data were collected.

The next modified version of the TERI model biogas plant was called Mark IV-B model, which had the slurry going through a diffuser, used with circular ferrocement plates. During 1987/88, four such plants – three in Dhanawas and one in Berka-Alimuddin (another village where TERI had been working) – were constructed. These modifications were based on the findings of laboratory research. The same year, TERI carried out some preliminary experiments on laboratory models of plants to obtain the RTD (residence time distribution) curves for various geometries and input mechanisms. The experiments confirmed that the effective residence time can be much smaller in conventional biogas plants. However, a configuration with a parallel plate diffuser gave an effective residence time closer to design HRT. This arrangement was introduced in the Mark IV-B model. The plant in Berka-Alimuddin functioned well during winters. Apart from cooking, it was also used for room heating and lighting. The plants constructed in Dhanawas also functioned well. The monitoring data (on gas production) showed that this model performed better than the previous ones and the gas production values were closer to the Deenbandhu model.

A variant of the diffuser inlet, a ferrocement slab with several apertures to distribute the input slurry, was also tried. This design was called Mark IV-C. Two plants of this design were constructed in Dhanawas and the monitoring data showed that the performance of this design was comparable to Mark IV-B. The Mark IV-C design was finally abandoned, as the ferrocement slab was inconvenient to install.

It was then thought that an inlet arrangement in which the slurry enters tangentially into a small chamber and then gets deflected would be a better alternative than the one where the slurry enters the digester directly. The box allowed the slurry to come out only from a lateral opening, thus preventing any upward movement, which might have resulted in short-circuiting. At the same time, the storage volume for the gas was increased by increasing the vertical distance from the highest slurry level to the gas outlet. This model was called Mark IV-D. Initial results of gas production monitoring showed that the performance was slightly better than that of the Deenbandhu plant. Two plants of the Mark IV-D model were constructed in Dhanawas. The schematic diagram of Mark IV-D model is given in Figure 2.

The next variant, called Mark V-A, had a lower HRT of 30 days. The Mark V-A was quite similar to Mark IV-D except that the diameter of the sphere was less. Ten plants of the Mark V-A design were constructed in Dhanawas. However, the performance of Mark V-A could not be established scientifically because of some data errors. Table 1 gives the details of variants of TERI biogas model installed in Dhanawas.

Domestic natural gas flow meters were installed for measurement. Except for January and February, the gas production figures for the Mark IV-D model were found to be comparable to those of the Deenbandhu model. Figure 3 gives the monthly average gas production values of the Mark IV-D model biogas plant.

The Mark IV-D model was also slightly cheaper (8.5%) than the Deenbandhu model. Table 2 gives a comparison of material requirement and costs of TERI Mark IV-D model and the Deenbandhu model.

Dissemination of Mark IV-D model

In 1995, TERI constructed Mark IV-D design biogas plants in Sultanpur village, Uttar Pradesh. These plants were constructed under a project funded by the Indian Oil Corporation and the Gas Authority of India Limited. As the performance of Mark V-A was rather uncertain, a decision was

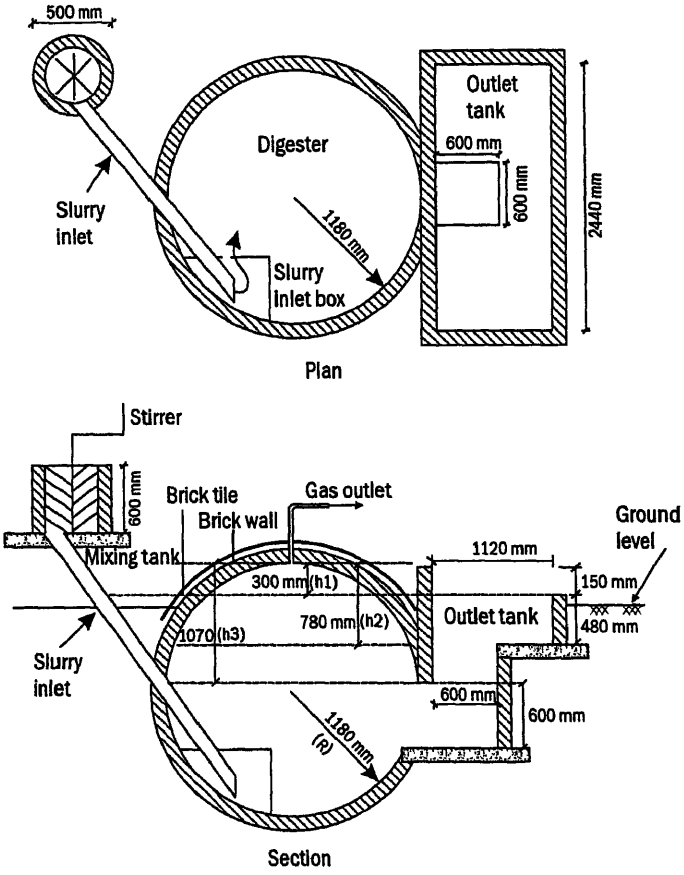

Figure 2 Schematic diagram of the Mark IV-D model
Source Kishore et al. (1998)

taken to install Mark IV-D design plants. Masons trained by TERI in Dhanawas were taken to Sultanpur for construction. A total of 24 plants were constructed. As of now, all the plants are functional and the user response is very good.

Compared to the Deenbandhu model, the Mark IV-D model in Dhanawas and Sultanpur offers the following advantages.

- *Simpler and faster construction.* Since the plant is spherical, the digestion and gas storage space merge to become single dimensional and hence are easier to construct.
- *Increased gas storage space.* As higher gas storage capacity is provided, the plant can be used more efficiently.

Table 1 Details of biogas plants installed in Dhanawas

Beneficiary	*Capacity (m³)*	*Year*	*Type*	*HRT (days)*	*Slurry mixing*	*Gas consumption (litre/day)*	*Dung input (kg/day)*	*Description*
Tula Ram	2	1985	1	50	Hand			Though a shallow solar pond was provided for hot water for mixing slurry, it was used for domestic application. As the joint family broke up, the plant was not used after one year.
Ram Niwas	2	1986	2	50	Hand	1213	30	In winter, slurry entered the gas line. The gas production rate was good. Greenhouse was introduced.
Ganpat	2	1986	3	40	Hand	1245		The dome was constructed without tiles. Hairline cracks were observed in the dome and there was gas leakage. Tiles were added later to repair the plant.
Krishan K	2	1988	4	40	Hand	1154	45	The dimensions of the slurry and gas outlets were modified. The problem of slurry entering the pipeline was solved.
Mahabeer S	2	1987	4	40	Hand	1466	49	
Mahender S	3	1988	4	40	Hand	1349	61	
Ganga Ram	2	1990	5	40	Stirrer			A stirrer was introduced to facilitate uniform and comfortable mixing of cow dung. slurry. Net was removed.
Puran Chand	2	1990	5	40	Stirrer			
Jaikishan	2	1991	5	40	Stirrer		37	
Rohtas S	2	1991	5	40	Stirrer			
Devendra S	2	1991	6	30	Stirrer		35	Perforated ferrocement plates were used instead of diffuser at the inlet. A shutter was introduced at the outlet.
Omwati	2	1991	6	30	Stirrer		47	
Krishan K	2	1992	7	30	Stirrer		40	The HRT was reduced to 30 days, and the perforated ferrocement plate and outlet shutter were removed because of the tangential inlet.
Shripal	2	1992	7	30	Stirrer		32	
Prem	2	1992	7	30	Stirrer			
Mangheram	2	1992	7	30	Stirrer			
Santram	2	1993	7	30	Stirrer			
Suresh K	2	1993	7	30	Stirrer			
Kartar Singh	2	1994	7	30	Stirrer			
Dhaniram	2	1994	7	30	Stirrer			

Note Type 1 curved bottom + stirrer; Type 2 flat bottom + nylon net; Type 3 spherical plant + nylon net; Type 4 spherical plant + diffuser + nylon net + perforated ferrocement plate; Type 5 spherical plant + tangential inlet + perforated ferrocement plate; Type 6 spherical plant + tangential inlet; Type 7 spherical plant + tangential inlet

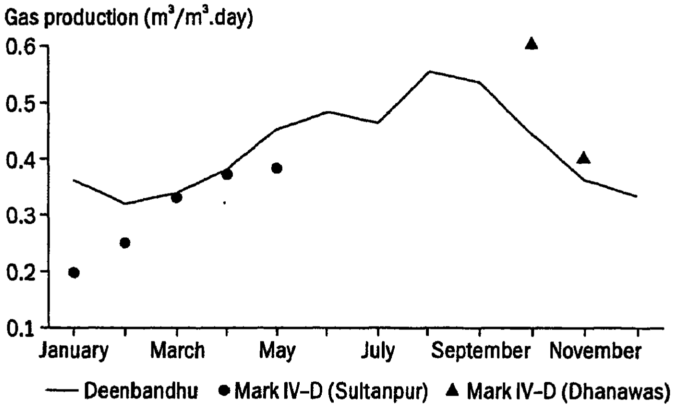

Figure 3 Monthly average gas production values of the Mark IV-D model

Table 2 Comparison of material requirement and costs of TERI Mark IV-D model and Deenbandhu model

Material	*Price/unit*	*Price (Rs at 1995-prices)*	*Quantity*		*Cost*	
			TERI	*Deenbandhu*	*TERI*	*Deenbandhu*
Bricks	Rs/no.	1.10	1200	1000	1320.00	1100.00
Tiles	Rs/no.	1.15	300	–	345.00	0.00
Cement	Rs/bag	150.00	9	14	1350.00	2100.00
Stone chips	Rs/ft³	5.50	–	40	0.00	220.00
Sand	Rs/ft³	4.50	75	40	338.00	180.00
Coarse sand	Rs/ft³	4.50	–	40	0.00	180.00
GI pipe	Rs/ft	30.00	1	0.7	30.00	21.00
AC pipe	Rs/ft	30.00	12	6	360.00	180.00
Outlet slab	Rs/m²	125.00	2	–	250.00	0.00
MS bar	Rs/kg	25.00	–	7	0.00	175.00
Cico	Rs/litre	20.00	3	–	60.00	0.00
Cement primer	Rs/litre	120.00	2	–	240.00	0.00
Paint	Rs/litre	120.00	–	1	0.00	120.00
Labour (pit)	Rs/man-day	40.00	10	10	400.00	400.00
Mason	Rs/man-day	125.00	9	11	875.00	1375.00
Labour	Rs/man-day	40.00	15	22	600.00	880.00
Miscellaneous	–	550.00	1	1	550.00	550.00
Stirrer	–	250.00	1	1	250.00	250.00
Gate valve	–	125.00	1	1	125.00	125.00
Pipeline	–	300.00	1	1	300.00	300.00
Stove	–	600.00	1	1	600.00	600.00
Biogas lamp	–	200.00	1	1	200.00	200.00
Total					8193.00	8956.00

Source Kishore et al. (1998)

- *No possibility of slurry entering the gas line.* The slurry and gas outlets are designed and placed such that the slurry is prevented from entering the pipeline due to low gas production, particularly in winters.
- *Low cost.* The spherical geometry also has a minimum surface area for a given volume and therefore reduces the cost.

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International Journal of Ambient Energy 19(4): 199–210

Annexure 2

Research and development on improved chulhas

Rural energy matters: the Dhanawas experience 181-184

Technology development was an important component of the improved chulha programme in Dhanawas. The focus of the research work was on assessing the technical and sociocultural feasibility of the improved models in the context of the cooking energy system of Haryana. A brief description of the technical experiments done by TERI is given below.

Assessment of thermal efficiency of improved models

In 1988, two types of tests were conducted to measure the actual thermal efficiency of the improved model vis-à-vis the traditional cooking system. These were (1) water boiling tests, and (2) kitchen performance tests. The objective was to assess the effectiveness of improved stoves in conserving energy.

Water boiling tests

There was a provision in the dissemination strategy for Nada stove to modify the design according to the number of pots used and user needs. To examine the results of the modifications on stove performance, water boiling tests were conducted on stoves installed during the demonstration phase before the users started using them but after the chulhas had dried adequately. The dimensions of the stoves were measured after they had dried. The port diameters of the Nada chulha were fixed based on the size of the frequently used pots. The height of the combustion chamber was decided by the size of the roti. Other dimensions were fixed using hand and finger measurement. Variation was observed in the distance between the two ports, probably because of the method of measurement. Besides these, the major design change was the removal of front dampers to facilitate roti-making along the stove wall.

Water boiling tests were carried out on 10 Nada stoves. The methodology of the water boiling test was similar to the one recommended by the Department of Non-Conventional Energy Sources consisting of a two-hour test with constant charge (325 g of wood every 15 minutes) of fuelwood. The results of the water boiling tests are given in Table 1.

The thermal efficiency varied between 10.8% and 19.6% with an average of 14.1%. Variation in the second port efficiency was more (1.4% to 8.6% with an average of 3.5%)

Table 1 Results of water boiling tests on Nada stoves

Stove number	Thermal efficiency (%) Port I	Port II	Total
1	8.1	2.7	10.8
2	8.0	3.7	11.7
3	10.0	1.8	11.8
4	9.4	3.1	12.5
5	11.1	2.0	13.1
6	9.8	3.9	13.7
7	13.6	1.4	15.0
8	12.2	4.1	16.3
9	12.3	4.0	16.3
10	11.0	8.6	19.6

Source Pal and Joshi (1989)

than that of the first port (8.0% to 13.6% with an average of 10.5%). While most of the reduction in the performance was attributed to the absence of front dampers, some of it was also due to the variation in stove dimension.

Kitchen performance tests

Kitchen performance tests were conducted to evaluate the impact of improved chulhas on overall household energy use. These tests were conducted in households that used (1) conventional stoves (fourteen), (2) TARA and conventional stoves (eleven), and (3) Nada stove (six). The test was carried out after the stoves had been in use for about four months. The purpose of the test was explained to the households, and they were requested to use the hara only for simmering milk. The use of the hara was not included in the kitchen performance tests, as it was not affected by the improved wood stoves. The households were requested to keep the fuels to be used in a separate area. The different fuels used by the households were weighed separately, using a spring balance. The samples of fuels were collected from each household for measuring their moisture content. Details regarding family composition (number of children, women, men, and elderly people) were also collected. The measurements in a household were made daily at a fixed time for six consecutive days. Table 2 gives the details of fuel used and food cooked according to the stoves used.

The DAEC (daily per adult energy consumption) varied between 9 MJ and 44 MJ for all categories of households. The

Table 2 Daily per adult fuel used and meal cooked (kg)

		Fuel						*Meal*			
		Crop residues		*Fuelwood*		*Dung cake*		*Roti*		*Others*	
Stove combination	*No. of households*	*Avg.*	*SD*	*Avg.*	*SD*	*Avg.*	*SD*	*Avg.*	*SD*	*Avg.*	*SD*
TARA and conventional	11	2.33	1.52	2.28	1.86	4.45	2.73	0.70	0.23	5.66	2.53
Nada	6	2.08	0.94	0.51	0.57	3.80	1.32	0.70	0.25	5.40	2.01
Conventional	14	3.11	1.92	2.40	1.48	4.66	4.09	0.82	0.51	7.20	3.93

Note Avg. - average; SD - standard deviation
Source Pal and Joshi (1989)

DAEC values greater than 30 MJ were observed in households using conventional stoves (Table 3).

Table 3 Comparison in energy consumption of different combinations of stoves

Stove combination	*No. of households*	*DAEC (MJ)*	*Saving over conventional stove (%)*
Conventional	14	22.14 ± 7.32	
TARA + conventional	11	19.55 ± 5.12	11.70
Nada	6	19.32 ± 2.28	12.74

Source Pal and Joshi (1989)

Results of the kitchen performance tests showed that the existing designs of metal stoves can save more energy (approximately 32%) than that saved by the mud stoves (approximately 20%). However, the usage of metal stoves was limited, particularly in households where rotis were made on the vertical stove walls. The metal stoves had a life of about two years. The metal stoves also had a limited demand in houses in the agricultural field and were used only occasionally.

Introducing cement chulhas

In 1989, TERI constructed the first cement chulha in the village. The chulha had a chimney and was constructed with the support of the wall. The chulha was constructed outside the house. It was accepted well. In 1991/92, another cement chulha with chimney was tried. The chulha was again built outside. However, unlike the previous chulha, this was portable. This chulha was also very well accepted by the household.

Finally, in 1996, the improved cement chulha programme was launched in the village under which 20 chulhas were constructed.

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